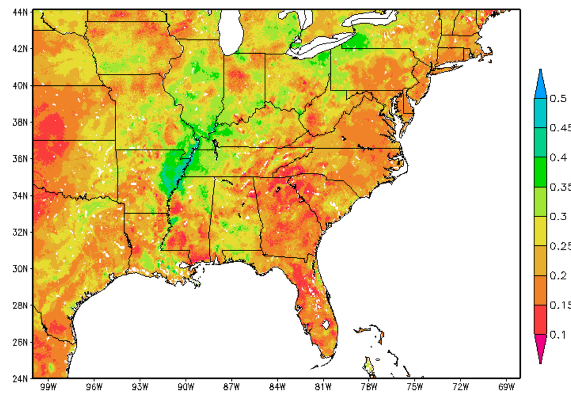
SMAP Assimilation Impacts on Land Surface and Numerical Weather Prediction Models



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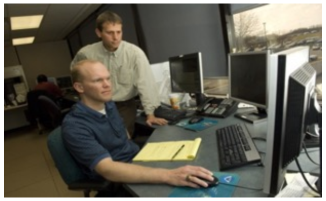
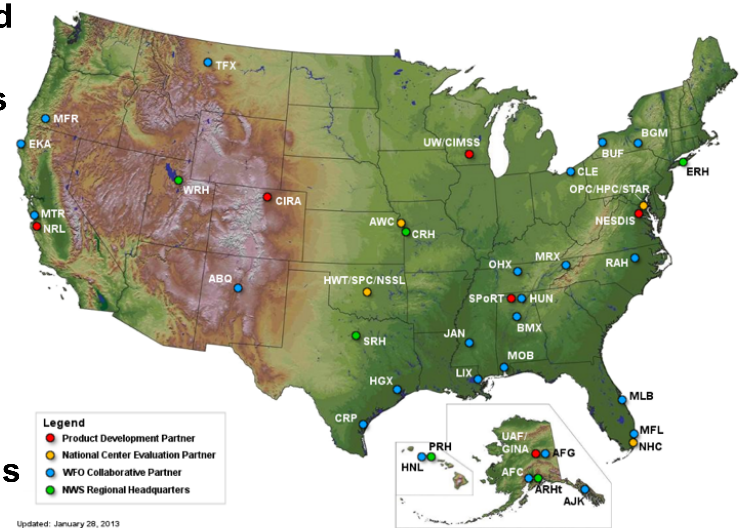


Short-term Prediction Research and Transition (SPoRT) Center

<u>Mission</u>: Transition unique NASA and NOAA observations and research capabilities to the operational weather community to improve short-term weather forecasts on a regional and local scale.

- **Close collaboration with numerous WFOs and National Centers across the country**
- **SPoRT activities began in 2002, first products to AWIPS in 2003**
- **Co-funded by NOAA since 2009 through Proving Ground activities**
- **Proven paradigm for transition of research and experimental data to operations**



<u>Benefit:</u>

- **Demonstrate capability of NASA and NOAA experimental products to weather applications and societal benefit**
- **Take satellite instruments with climate missions and apply data to solve shorter-term weather problems**

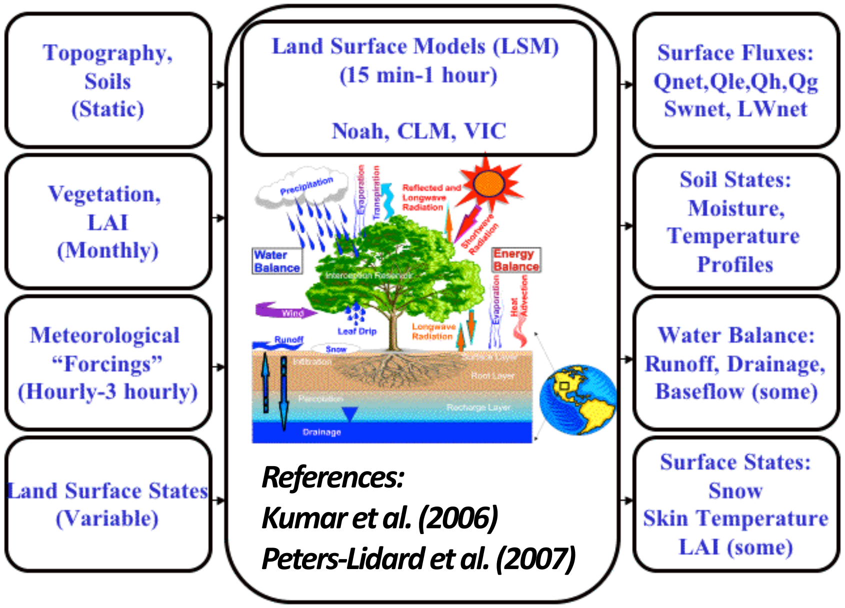
Overview of Project

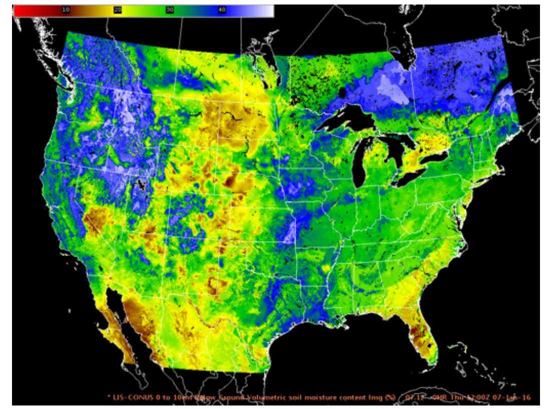
Domain	CONUS	East Africa
Assimilate SMAP in LIS Evaluate soil moisture vs. station measurements	✓ In progress	
Coupled NU-WRF Experiments (LIS+WRF) Evaluate 48-h weather forecasts	Preliminary	

Refinement of methodology

- Vertical layers
- Bias correction methods
- Ensemble size, perturbations, weighting

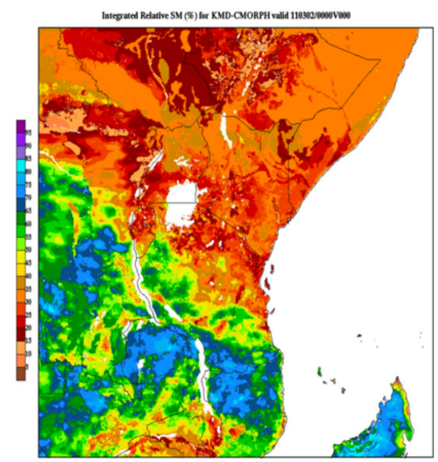
Land Information System (LIS)





SPoRT-LIS total column soil moisture displayed in AWIPS II

- Framework for running LSMs incorporating a wide variety of meteorological forcing data and land surface parameters
  - Developed by NASA-GSFC
  - Includes data assimilation capability.
  - Can be run coupled with Advanced Research WRF.
- Using Noah 3.3 Land Surface Model (LSM) within LIS
- SPoRT maintains near-real-time and experimental LIS runs
  - SE US (3-km), shared with WFO's
  - East Africa, shared with Kenya Meteorological Service (KMS)



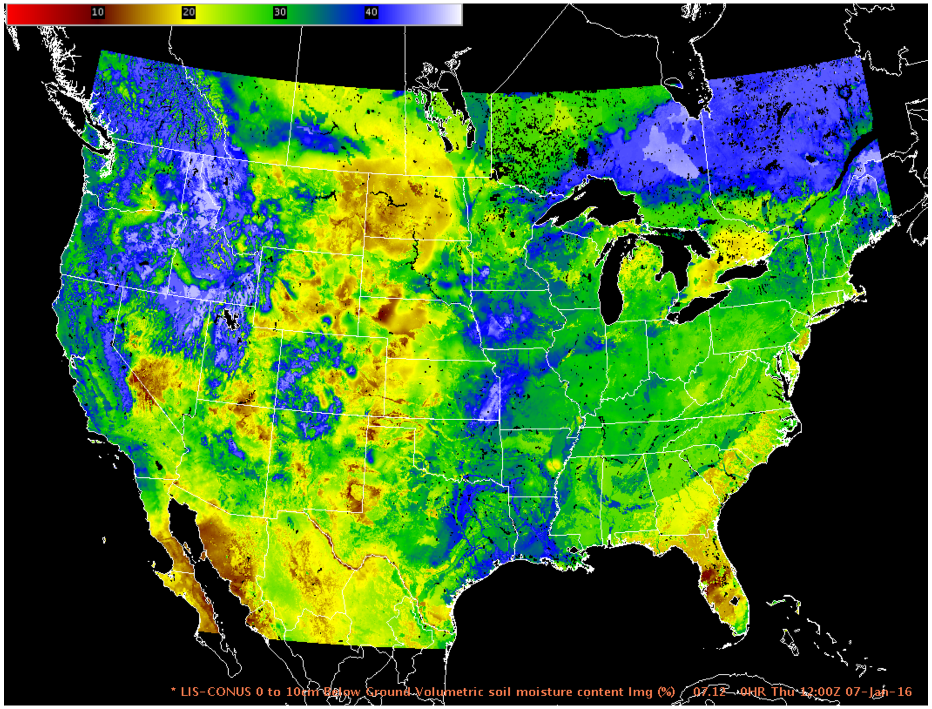
East Africa LIS domain

SPoRT LIS Unique Features

Full Continental U.S. (CONUS) domain with 0.03° (lat/lon) grid resolution

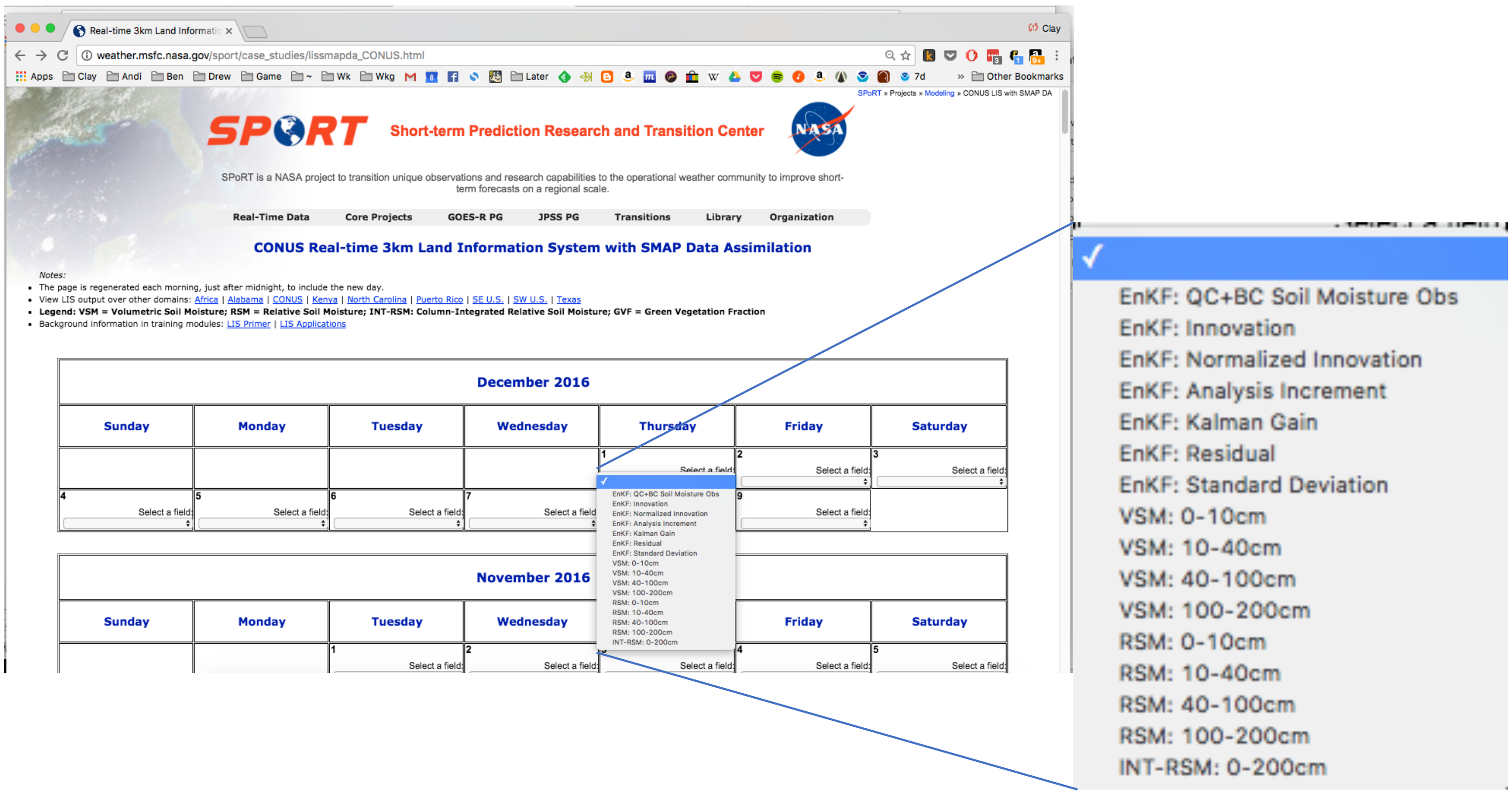
Unique characteristics of SPoRT-LIS:

- Real-time S-NPP/VIIRS Green Vegetation Fraction
- Albedo scaled to input vegetation
- Restart simulation strategy to produce real-time output (timeline below)
- **SPoRT-LIS ingested and displayed in AWIPS II at select NOAA/NWS weather forecast offices**
- Land surface variables available to initialize modeling applications (WRF and STRC/EMS/UEMS)



Current SPoRT-LIS CONUS domain,
as displayed in AWIPS II

SPoRT LIS Web Interface



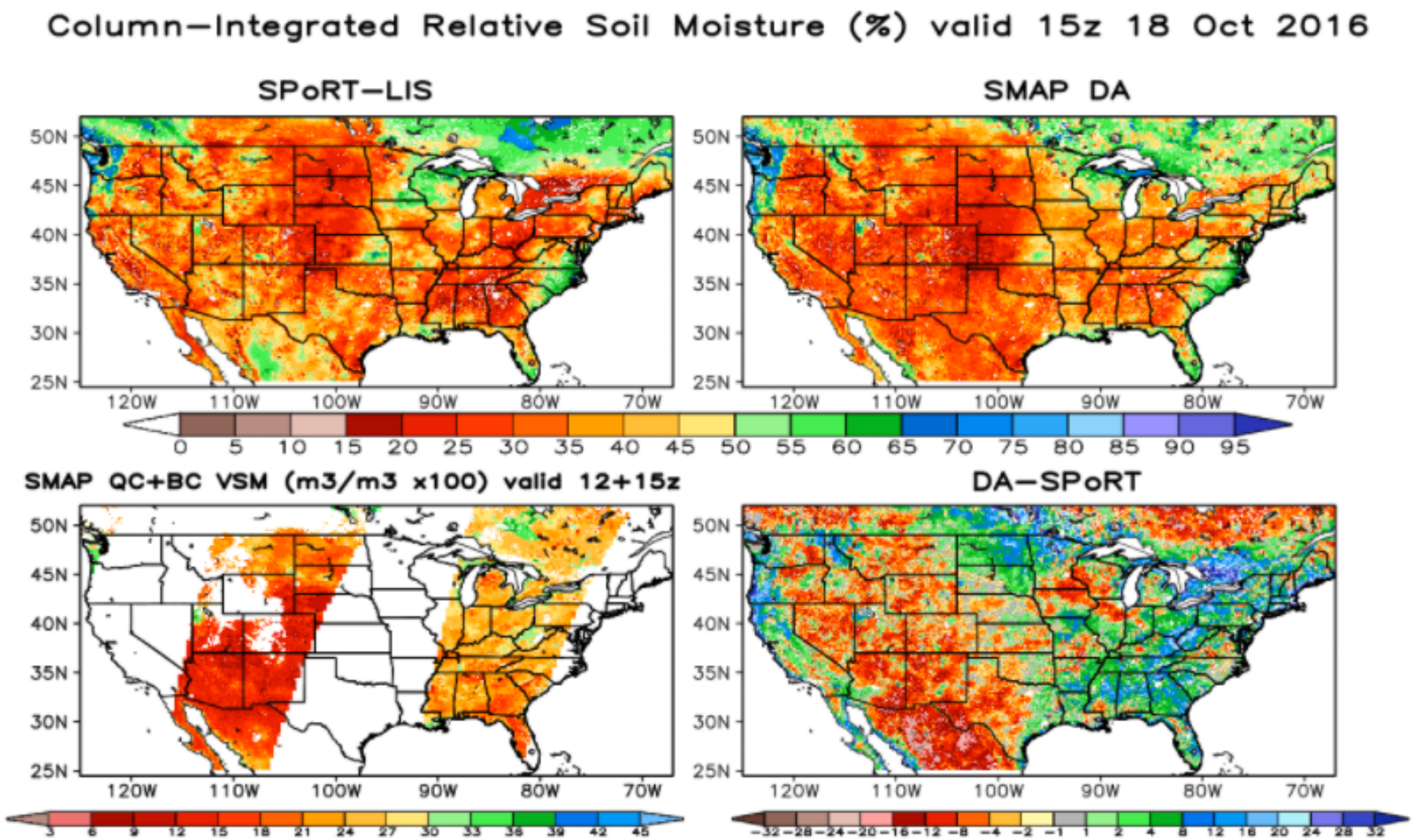
https://weather.msfc.nasa.gov/sport/case_studies/lissmapda_CONUS.html

or https://weather.msfc.nasa.gov/sport ->Real-Time Data

->Land Information System

-> SPoRT LIS + SMAP DA

LIS Web Products from SPoRT: SMAP LIS



- 0-10 cm model soil moisture

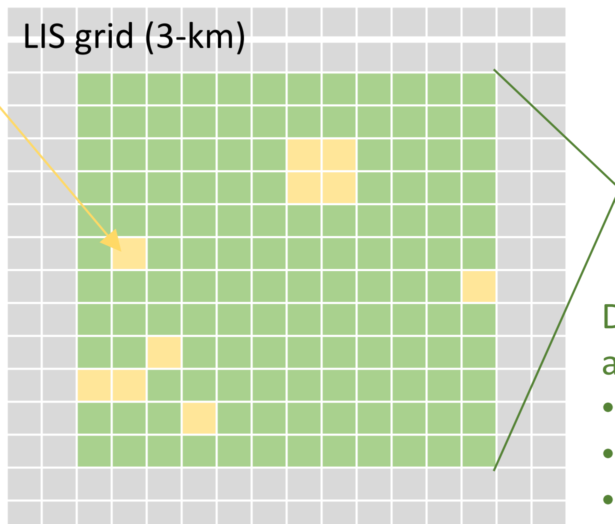
https://weather.msfc.nasa.gov/sport/case_studies/lissmapda_CONUS.html

Sampling Strategy

- Level 2 data are available on 36-km EASE grid
- To take advantage of high resolution geophysical properties (topography, vegetation, soils), running model at 3-km
- SMAP observations are assimilated at each model grid point in their FOV
- Downscaling to preserve background variability implemented

Some QC applied on LIS grid
Depends on LSM/variable
(e.g. Noah3.3+soil moisture)

- Precip (changed to 1 mm/hr)
- Frozen ground
- Snow on ground
- GVF>0.7
- Extreme values



SMAP (passive)
36-km cell

Data flag-based QC applied at observation resolution

- **Retrieval Quality Flag**
- Vegetation Opacity
- Vegetation Water
- Frozen Ground Fraction

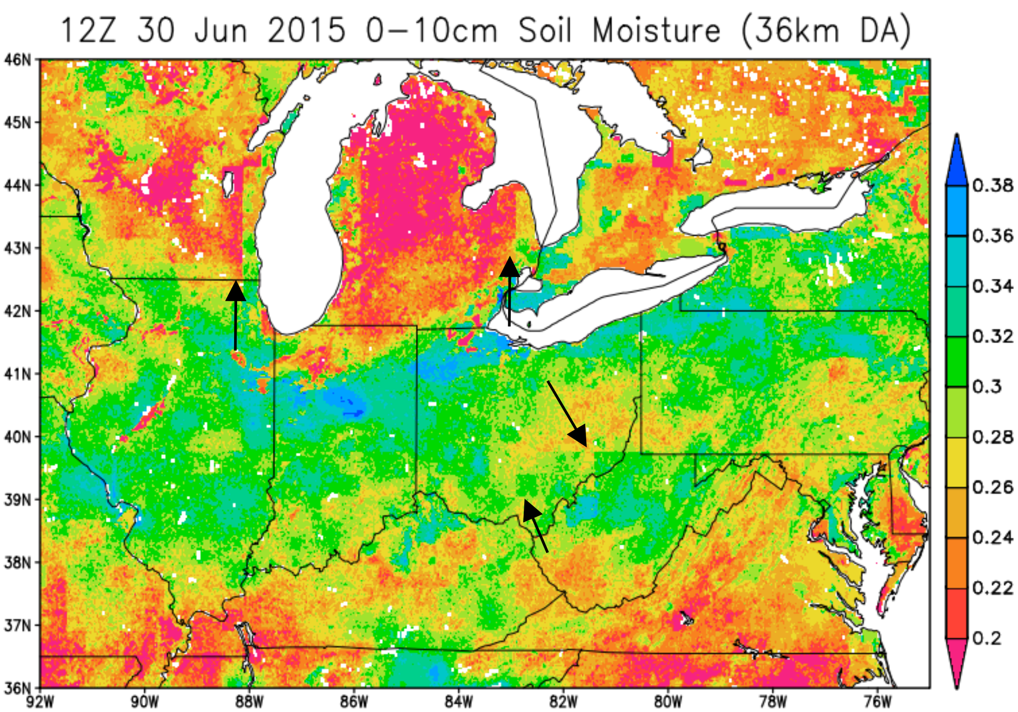
Bias correction will be applied on LIS grid.

SMAP and LIS grids are not aligned. Near boundaries, keep only one observation per cell (closest good ob)

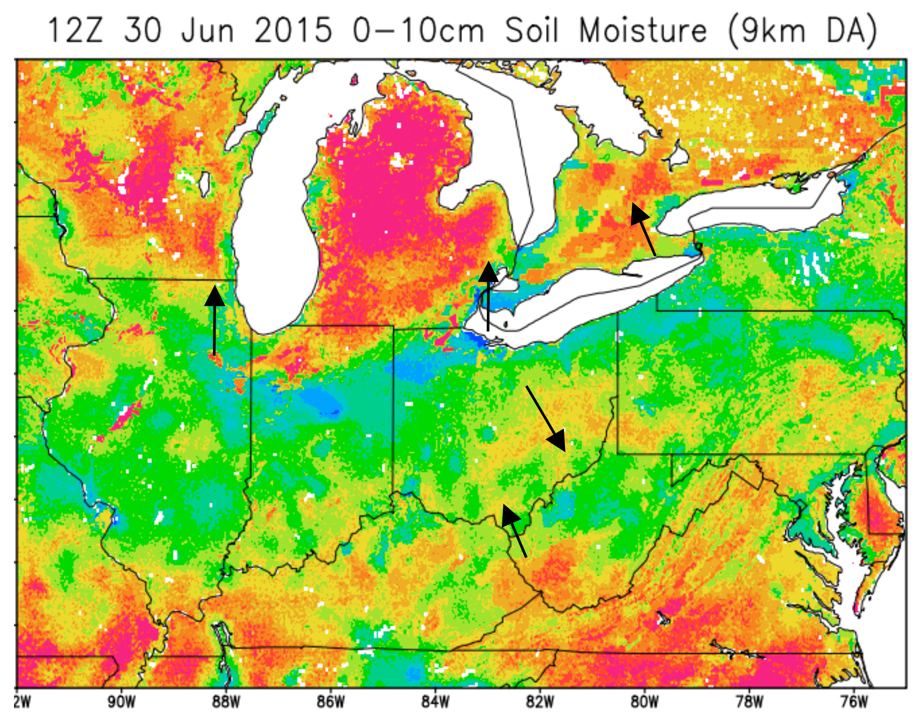
Assimilation of SMAP Enhanced (9-km) Product

0-10 cm Volumetric Soil Moisture (%)

LIS with 36-km SMAP DA

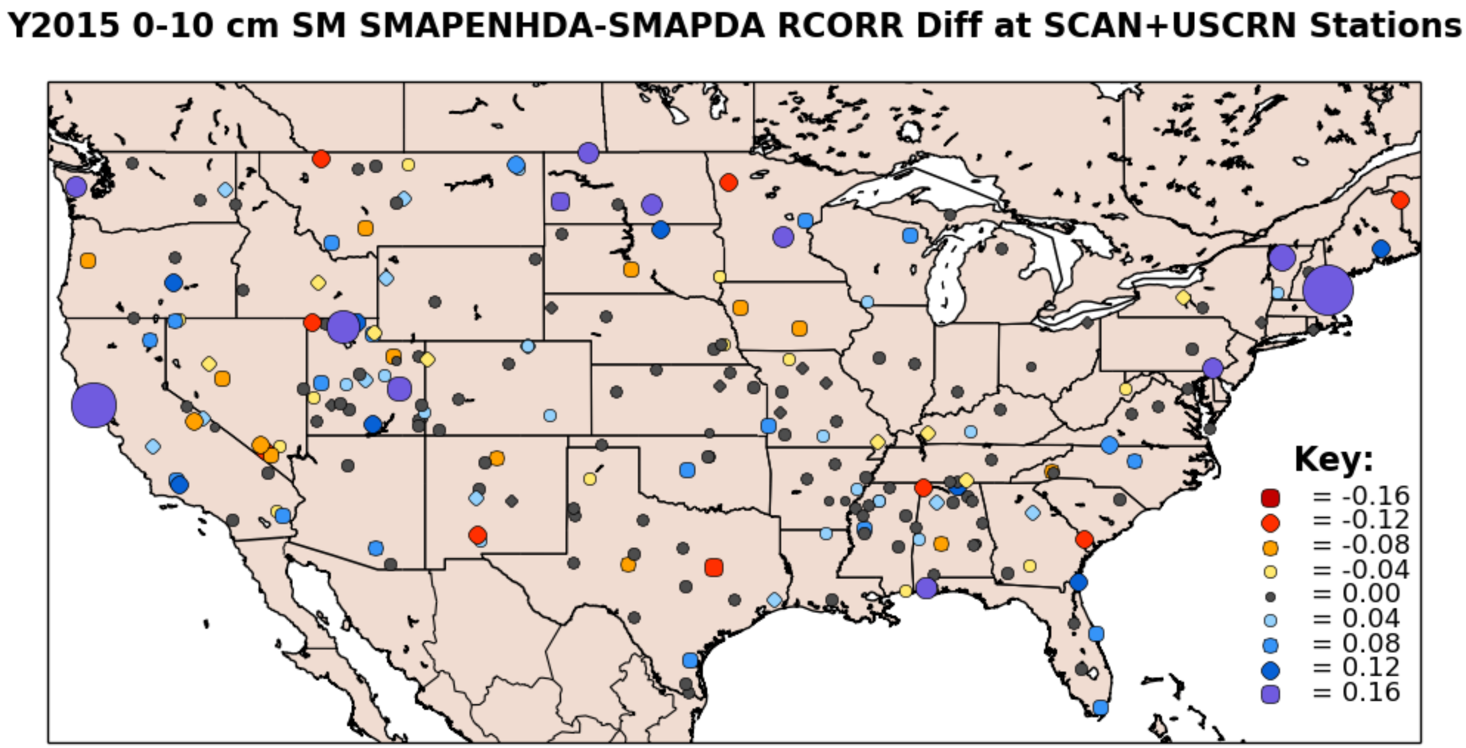


LIS with 9-km SMAP DA



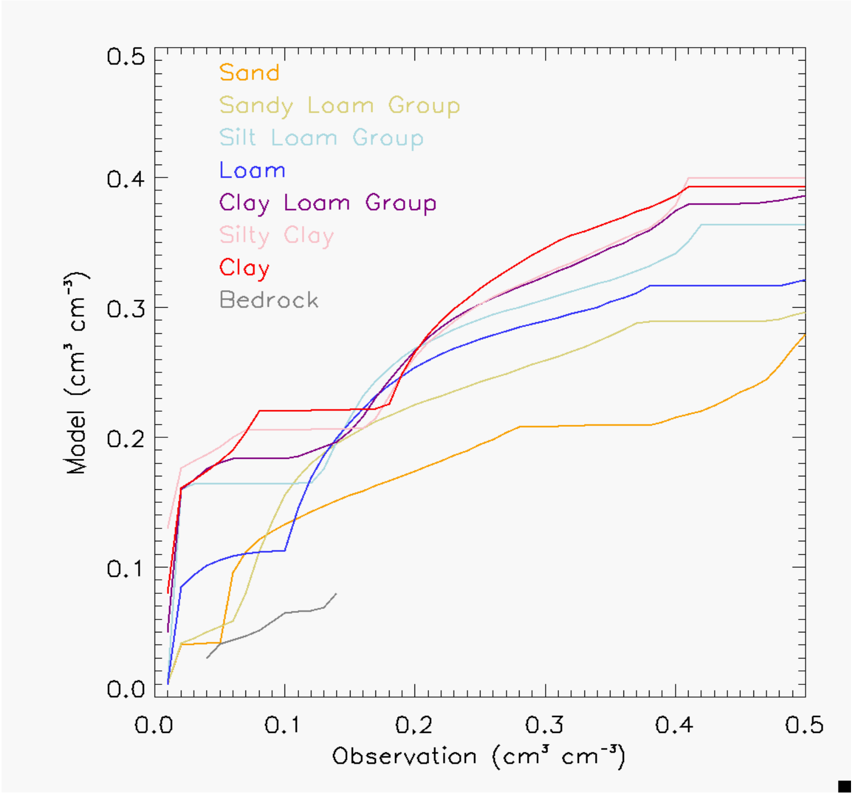
Note linear and square features (e.g., at arrows) on left resulting from the coarse 36-km resolution of the SMAP data. Reduced on right due to using 9-km Enhanced SMAP data.

Impact of Enhanced SMAP (correlations)



Bias Correction

- Assimilation systems assume unbiased observations
- LIS can apply point-by-point correction curves. Many implementations generate climatologies of model and obs at each grid point.
- We have implemented CDF matching aggregated by soil type
  - Described for SMOS in Blankenship et al. 2016 (*IEEE TGRS*)
  - Idea is to let the observations influence the model climatology
- Other methods will be explored including using only nearby points
- Using a thinner soil moisture layer may reduce forward operator error and subsequently the magnitude of bias corrections



Correction Curves By Soil Type

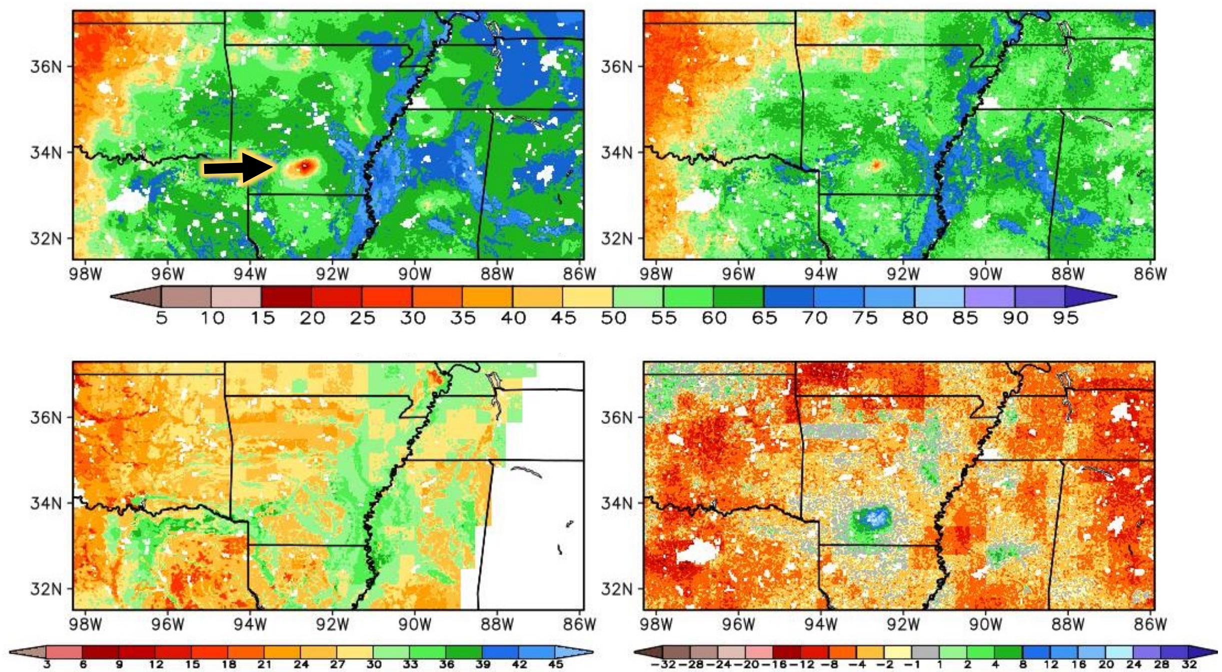
SMAP Assimilation Reduces Errors due to Poor QC in Forcing Data

- Land surface models such as SPoRT LIS are forced using precipitation inputs (NLDAS-2 in this case)
- In 2015, NLDAS-2 included data from a bad rain gauge (consistently near zero) in southern Arkansas causing an anomalously dry soil moisture “bullseye” (upper left, arrow).
- Through assimilation of SMAP L2 soil moisture fields, which do not exhibit this feature (lower left), this anomaly is greatly reduced over time (upper right) to provide a more representative soil moisture field.
  - Snapshot is 24 days after beginning of assimilation.
- This results in a more accurate depiction of local conditions.

0-2 m Column Integrated Relative Soil Moisture (%)

12Z 24 Apr 2015

Baseline SPoRT LIS **SPoRT LIS with SMAP DA**



SMAP Retrieved Soil Moisture
0-5 cm, volumetric (m^3/m^3 x100)
Non-localized CDF-matching bias correction applied

LIS Difference
(SMAP DA Minus Baseline SPoRT)
Column Integrated RSM (%)

Credit: Youlong Xia, Pingping Xie (NCEP/EMC); David Mocko (NASA/GSFC)

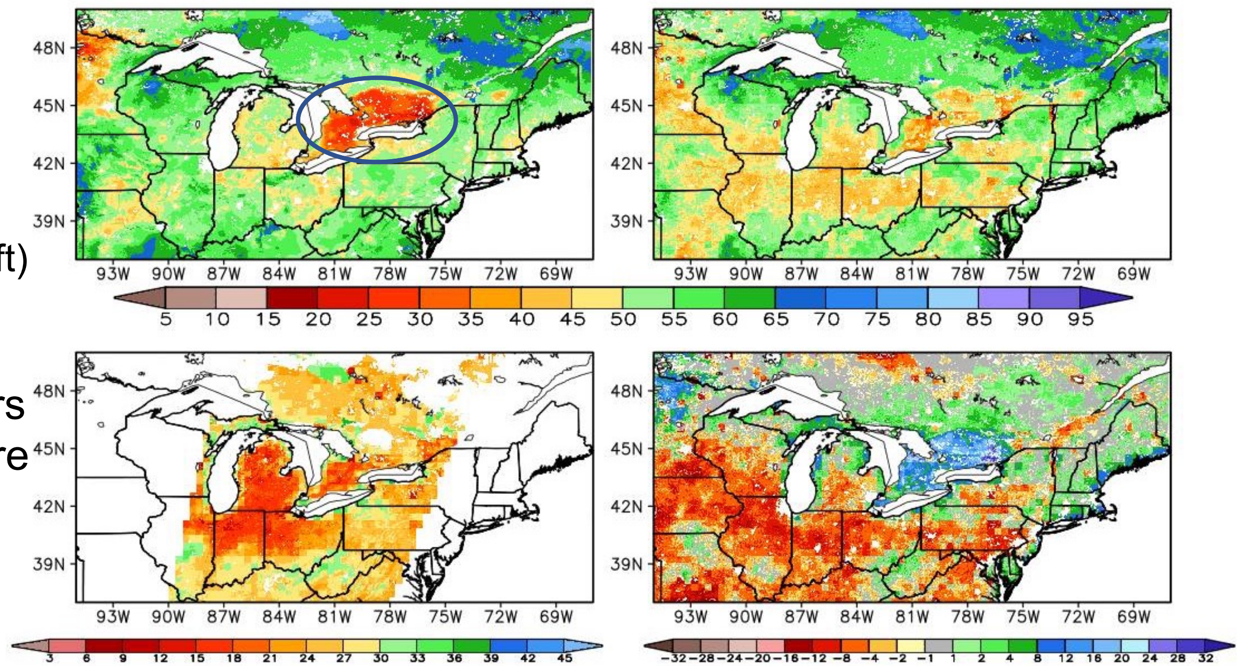
Better Blending of Soil Moisture Across US-Canada Border

- Soil moisture discontinuities can occur in regions where different precipitation inputs are blended
  - NLDAS-2 uses radar-derived precipitation over U.S. and reanalysis outside of U.S.
  - Results in anomalous dry conditions in southern Ontario (upper left, oval)
  - SMAP retrieved soil moisture (lower left) does not have this feature.
- Through assimilation of SMAP L2 soil moisture fields, this anomaly disappears over time (upper right) to provide a more representative soil moisture field
- This should help forecasters better assess current regional conditions and provide more accurate initialization of NWP models.

0-2 m Column Integrated Relative Soil Moisture (%)

12Z 4 Jun 2016

Baseline SPoRT LIS | **SPoRT LIS with SMAP DA**



SMAP Retrieved Soil Moisture
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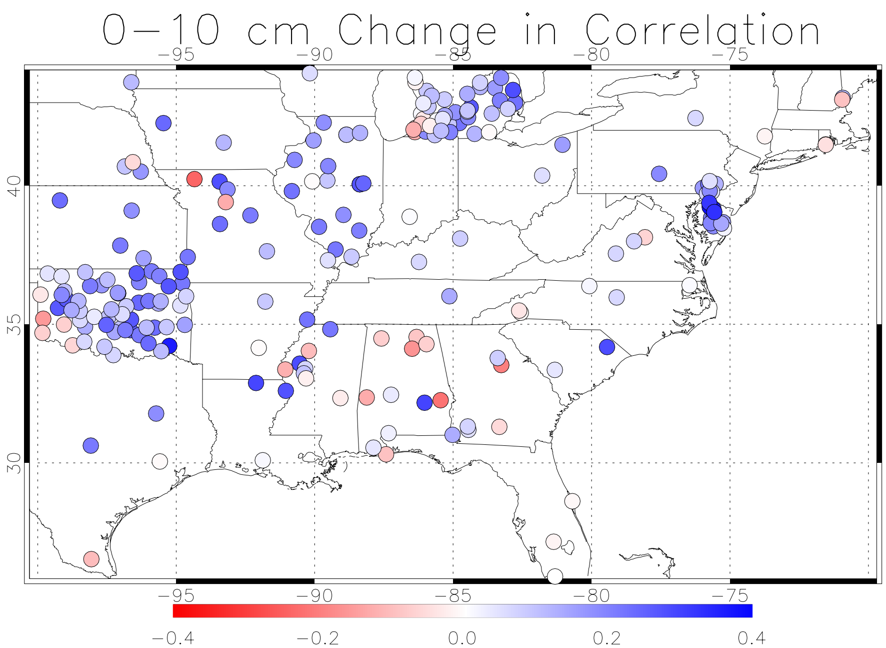
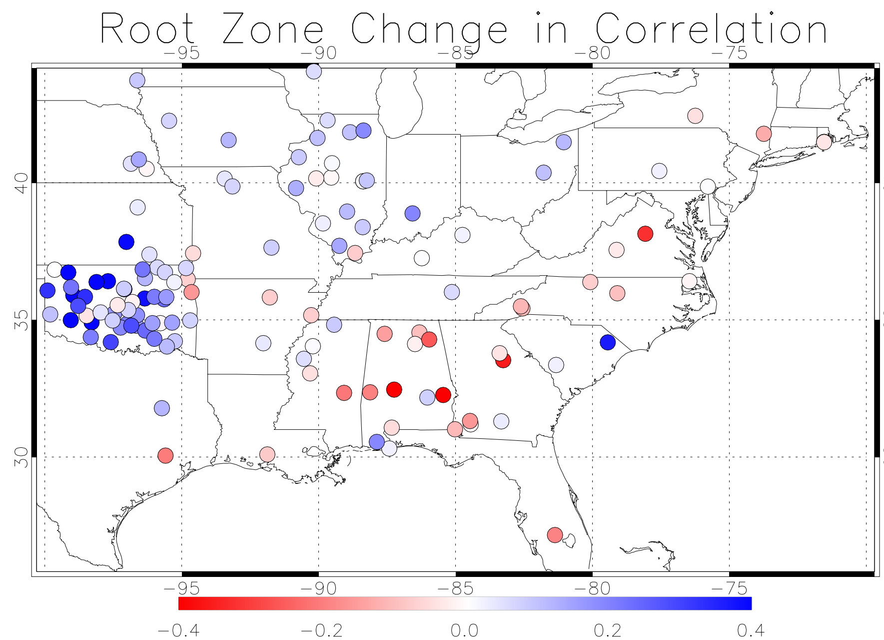
LIS Difference
(SMAP DA Minus Baseline SPoRT)
Column Integrated RSM (%)

Credit: Youlong Xia, Pingping Xie (NCEP/EMC); David Mocko (NASA/GSFC)

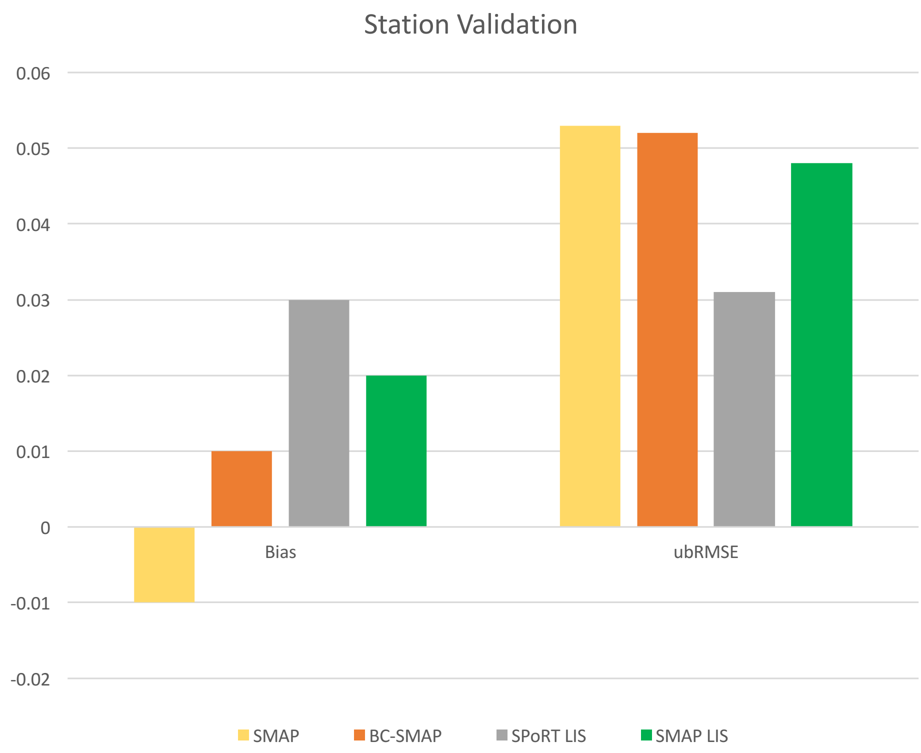
Previous Validation Results (SMOS DA)

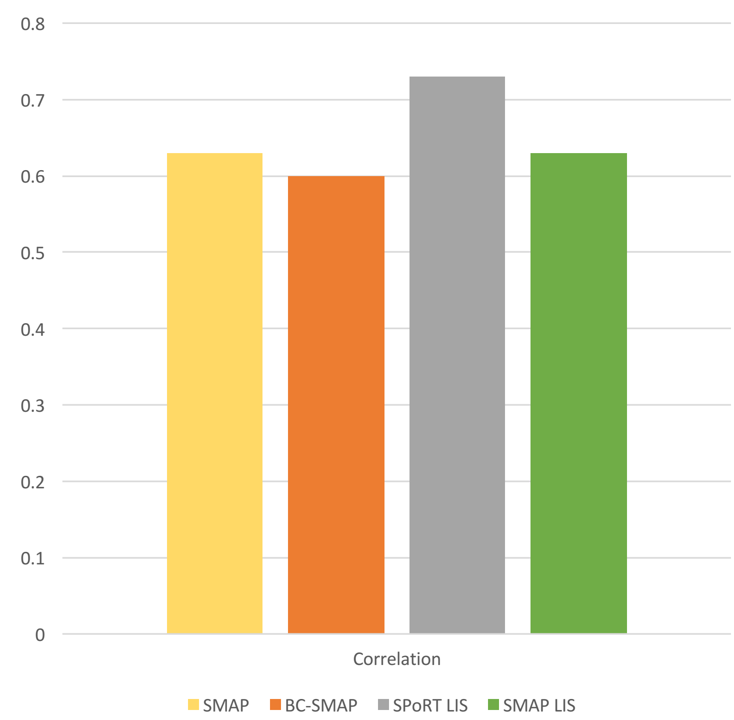




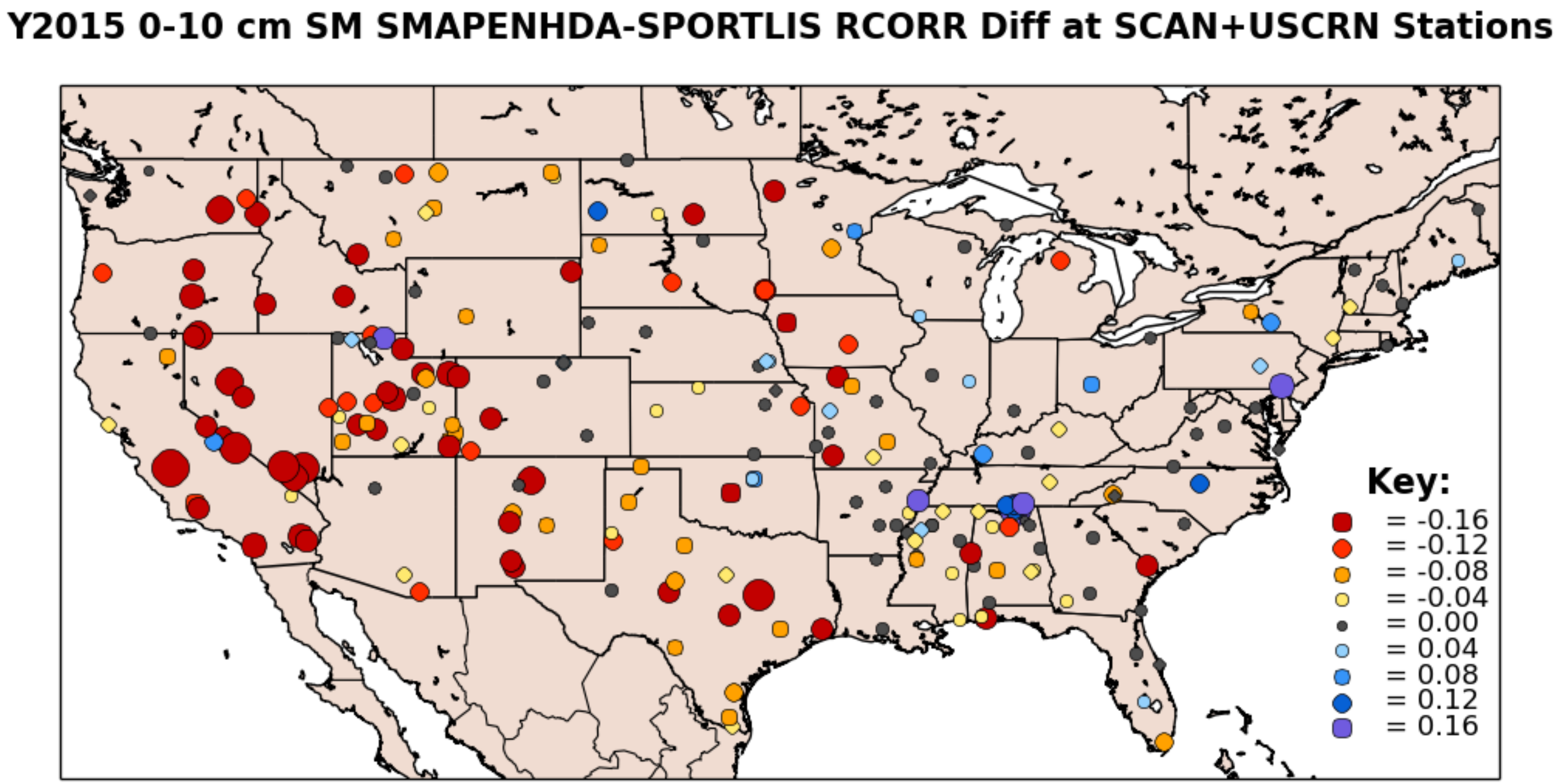
	Near Surface (0-10 cm)			**Root Zone (10-100 cm)**		
	Bias	Err SD	**Corr.**	Bias	Err SD	**Corr.**
Control	3.6%	23.5%	**0.47**	4.0%	10.6%	**0.61**
SMOS DA	-0.5%	21.8%	**0.57**	10.6%	11.8%	**0.67**

Quantitative Validation Results

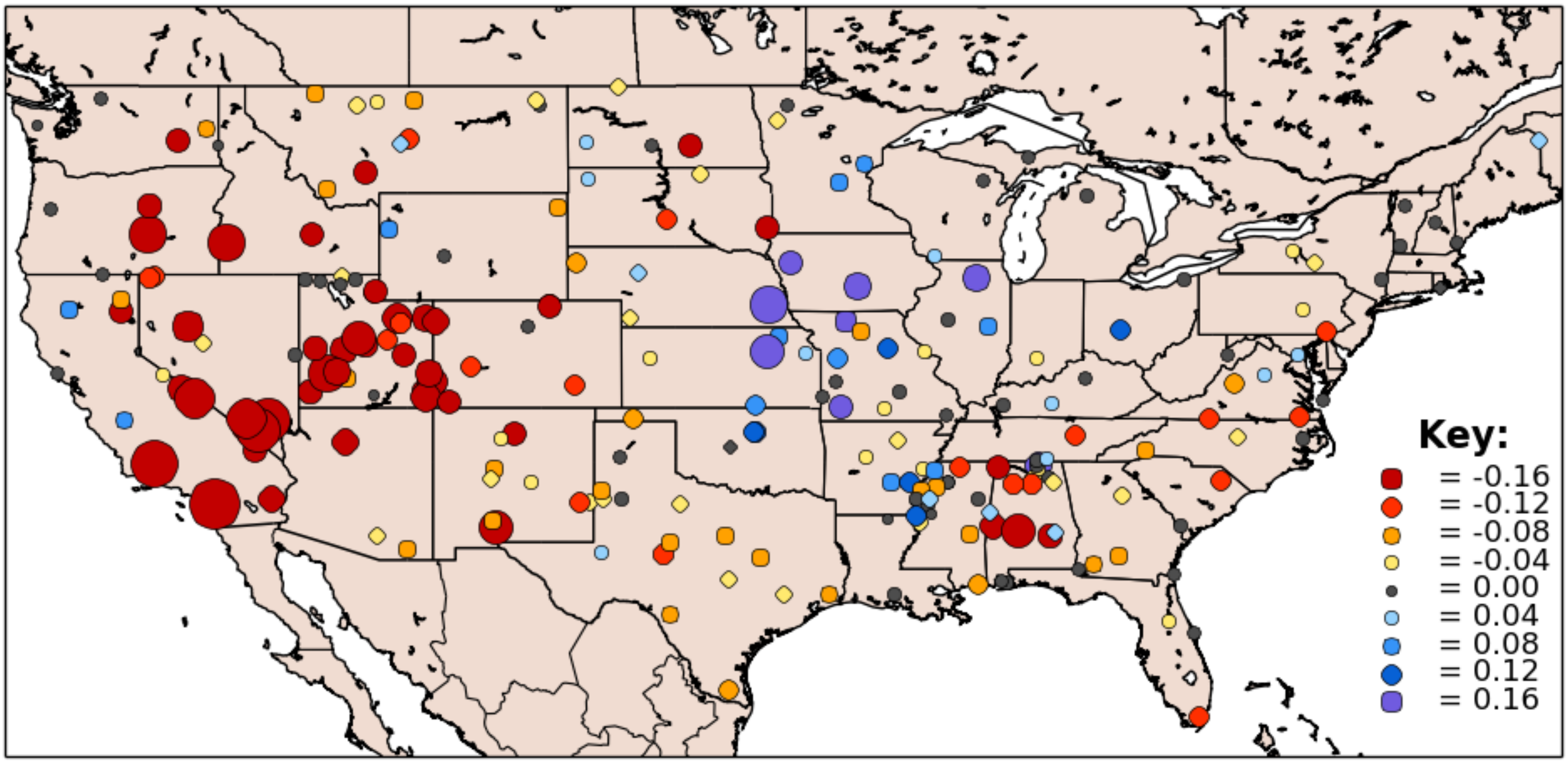




SMAP Correlation change 2015



Y2016 0-10 cm SM SMAPENHDA-SPORTLIS RCORR Diff at SCAN+USCRN Stations

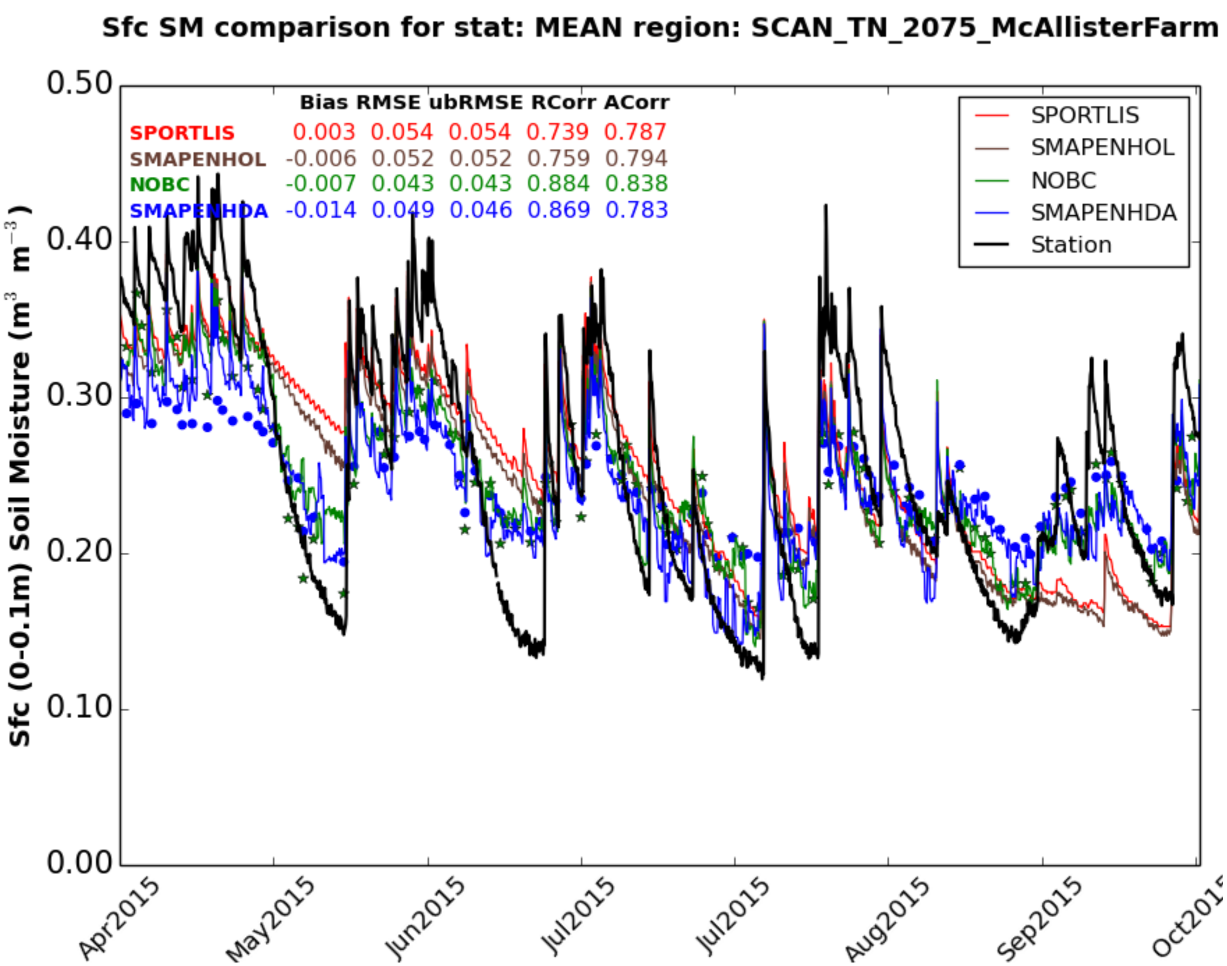


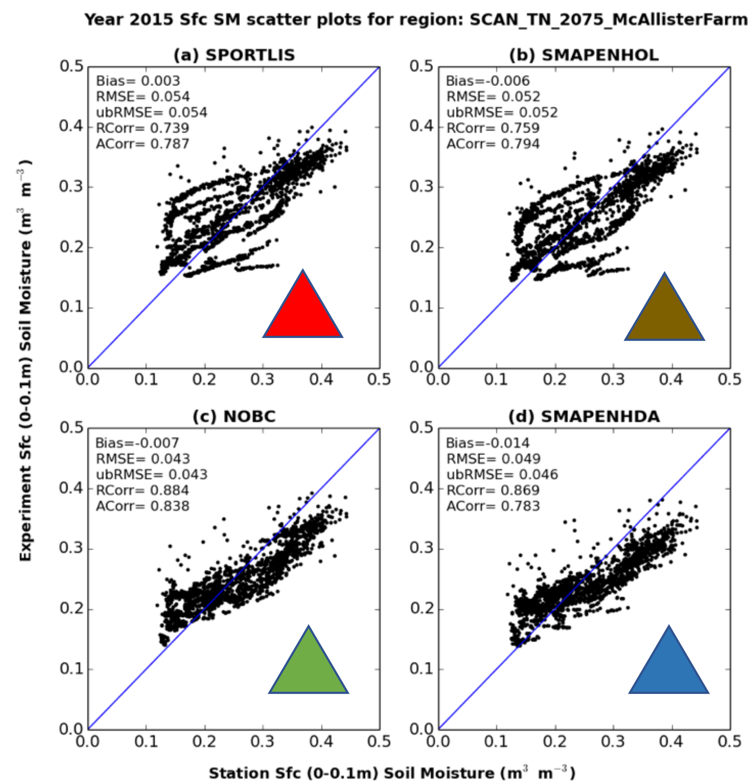
Possible Issues

- SMAP Data Accuracy
- Bias Correction
- AM/PM data
- Representativeness (point vs grid cell, also vertical) of validation data
- Depth discrepancies
  - (10 cm model layer, 5 cm or less SMAP measurement)
- Intial LIS is too hard to improve upon
  - 3-km resolution has more detail than 36 or 9-km observations
  - Forcing data (NLDAS-2) is high quality

New Validation Results (SMAP DA)

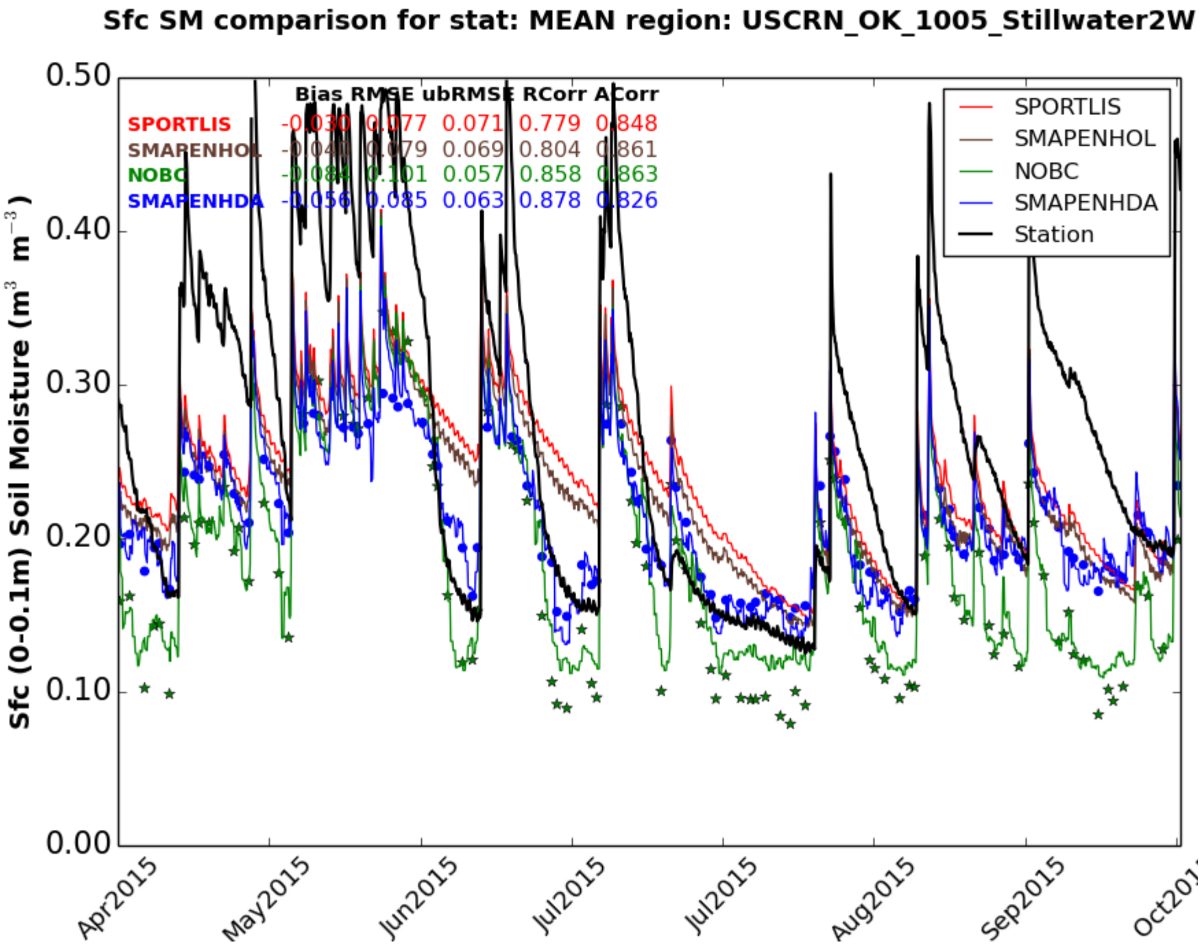
- Corr increases from .79 to .84 (NOBC)
- ubRMSE decreases from .054 to .043

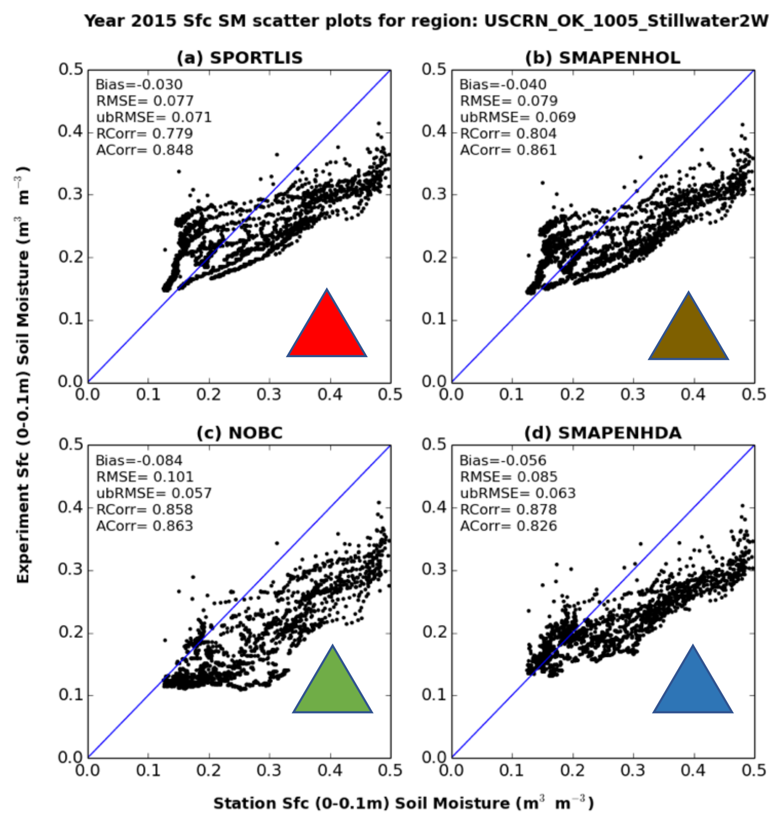




New Validation Results (SMAP DA)

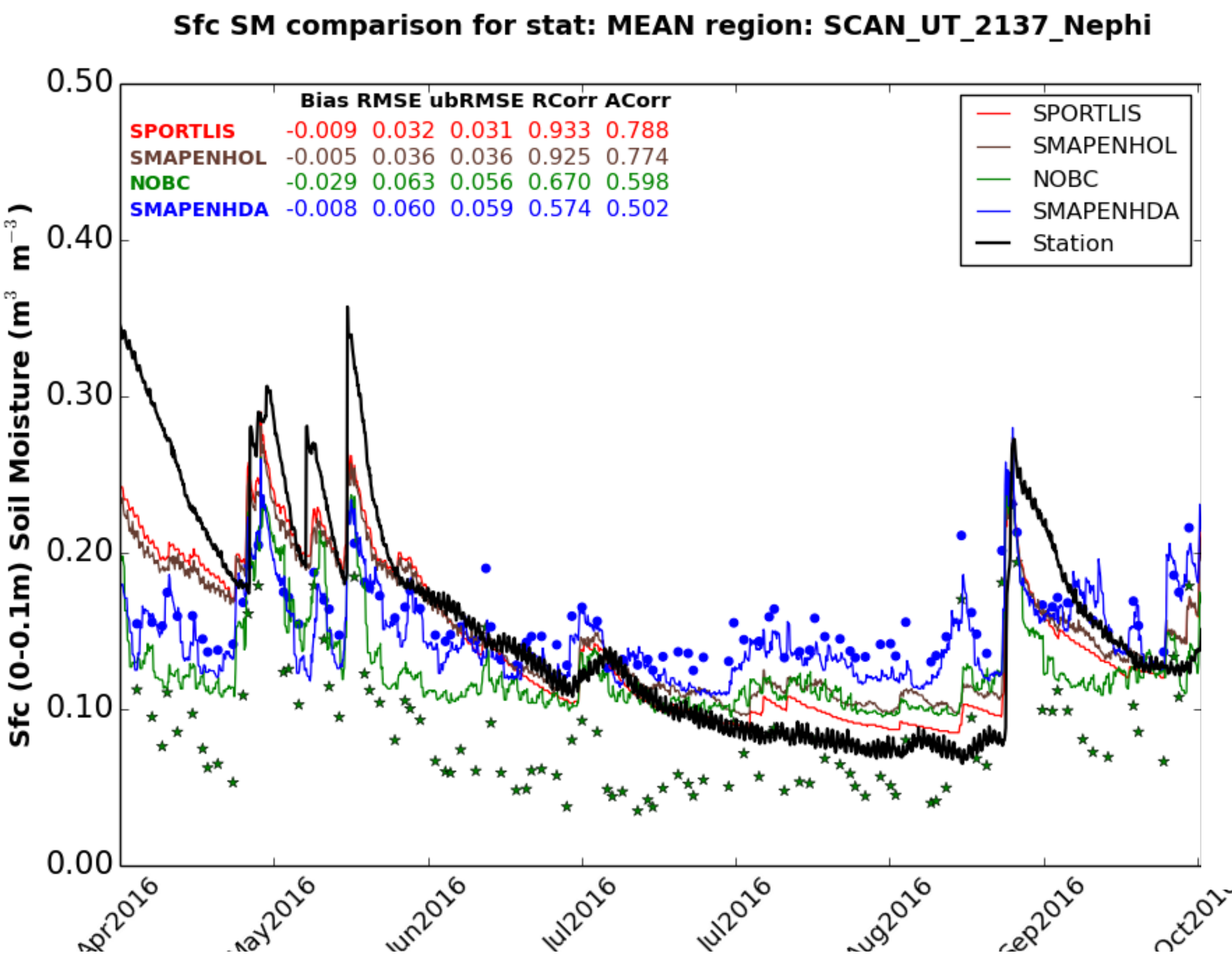
- Corr increases from .78 to 85 (NOBC)
- ubRMSE decreases from .071 to .057

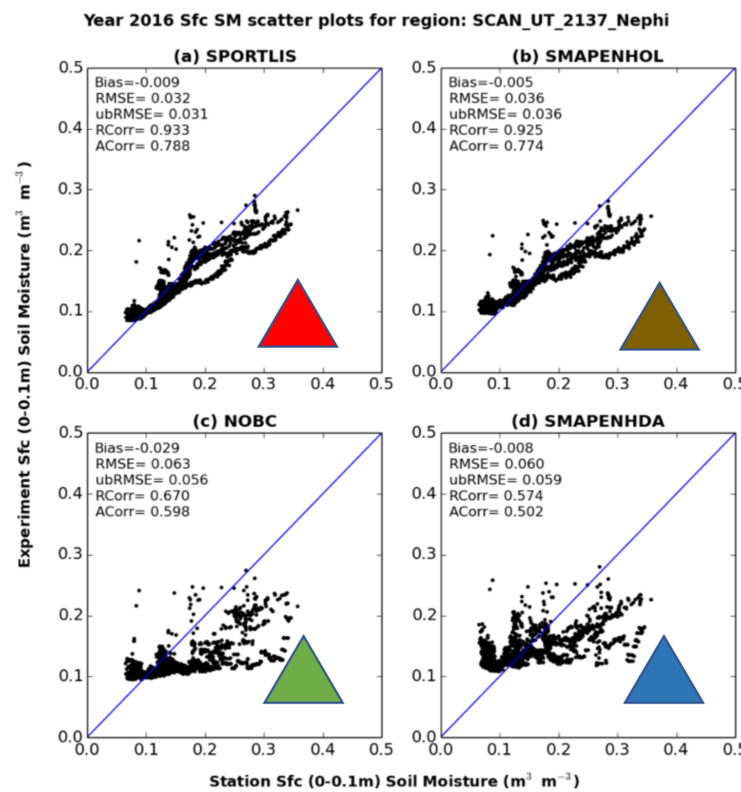




New Validation Results (SMAP DA)

- Corr decreases from .93 to .67 (NOBC)
- ubRMSE increases from .031 to .059



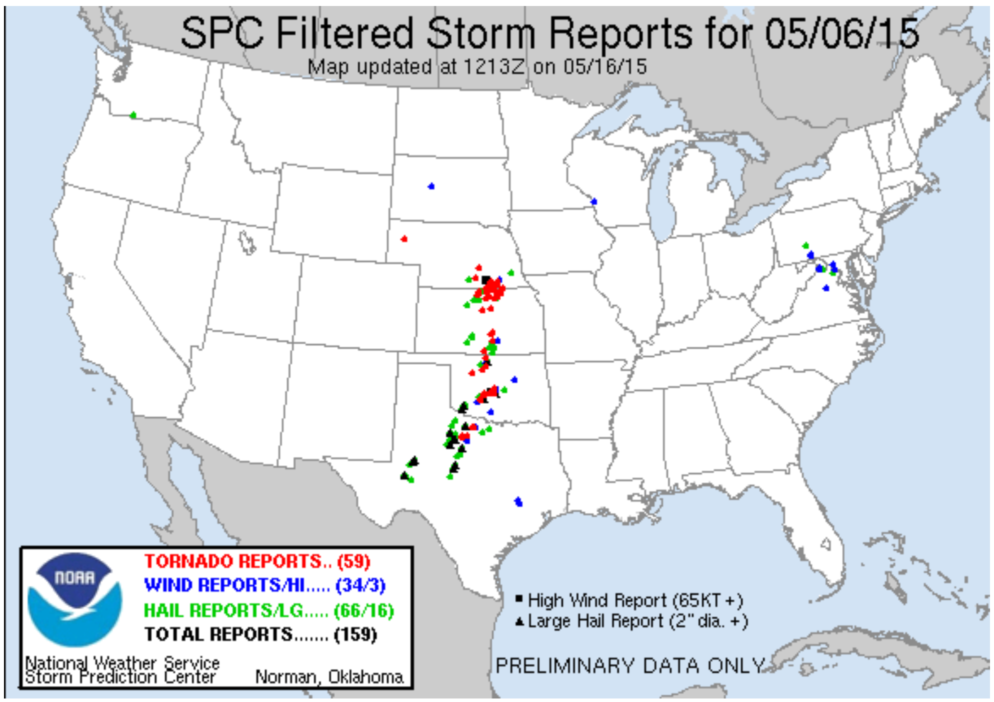


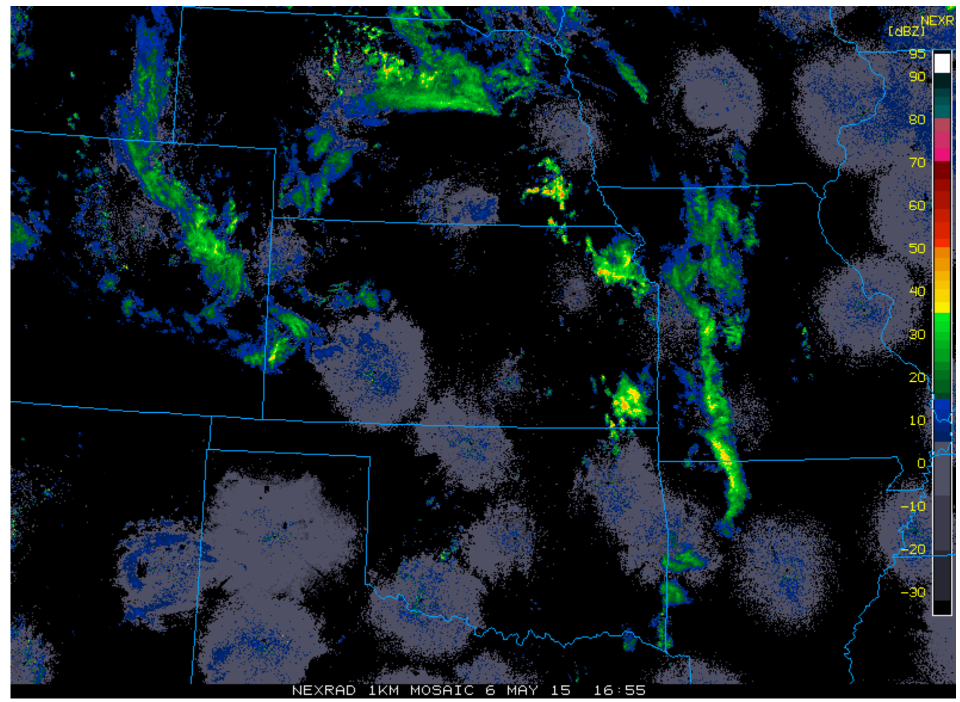
Possible Issues (and findings)

- Bias Correction
  - NoBC run indicates BC has a minor effect on statistics
- AM/PM data
  - Validation of retrievals indicates small difference
- Representativeness (point vs grid cell, also vertical) of validation data
  - Previously got positive impact (correlations) with SMOS
  - Others getting good impact
- Depth discrepancies
  - (10 cm model layer, 5 cm or less SMAP measurement)
  - Experiment in progress
  - Previously got positive impact with SMOS
- Information content of 3-km LSM is too hard to match with 9-km obs
  - Previously got positive impact with SMOS

6-7 May 2015 Southern Plains tornado outbreak:

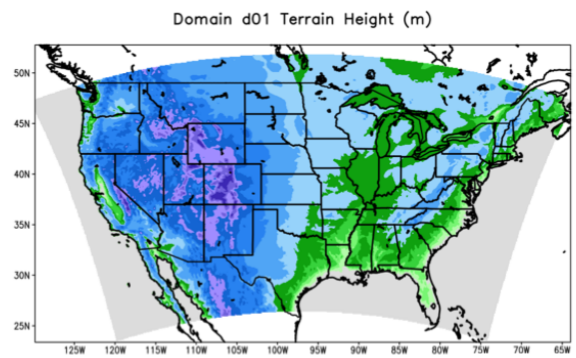
NASA Unified-WRF (NU-WRF) sensitivity simulations



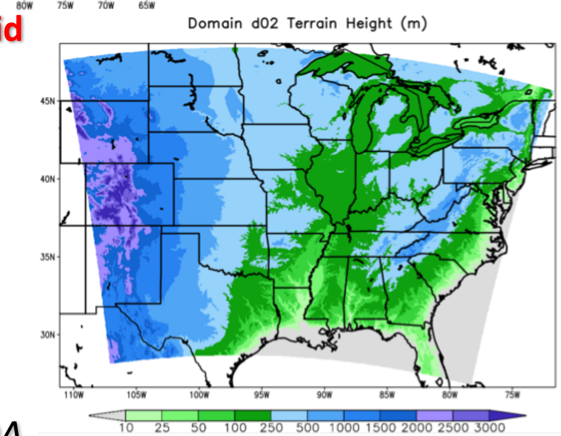


NASA Unified-WRF (NU-WRF) model runs:
Model configuration and experiment details

- Domain/grid set up (images at right)
  - *Contiguous U.S. at 9-km horizontal grid spacing*
  - *Convection-allowing 3-km mesh nested grid*
- Sixty-hour forecasts
  - *0000 UTC 6 May to 1200 UTC 8 May*
  - *Initialized at 0000 UTC 6 May 2015*
  - *Initial/boundary conditions from NCEP Global Forecast System model*
- Model physics parameterization choices
  - *Noah land surface model (same as in LIS runs)*
  - *Convection: Scale-aware Kain-Fritsch (9-km grid only)*
  - *Planetary Boundary Layer: Yonsei University scheme*
  - *Microphysics: NASA/Goddard 4-ice parameterization*
  - *Radiation: NASA/Goddard short- and long-wave radiation schemes*
- Two land surface initialization simulations
  - ***"sportlis":*** *0-h land surface fields from SPoRT's "operational" LIS run; no DA*
  - ***"smapenhda":*** *0-h land surface fields from SMAP-Enhanced DA LIS run*



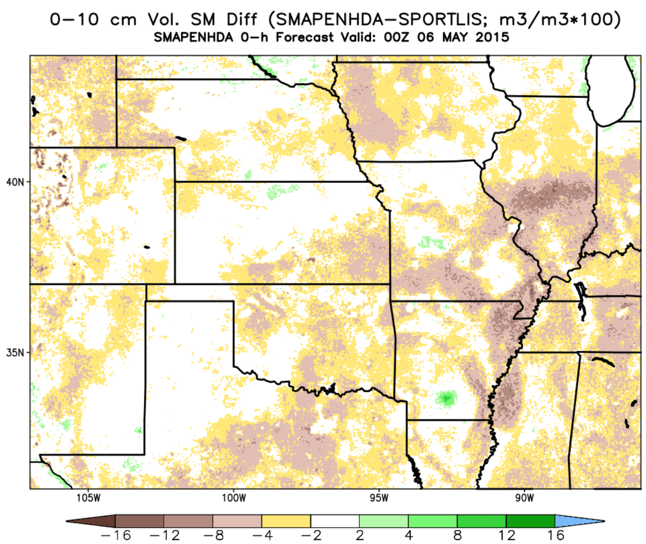
9-km primary grid



3-km nested grid

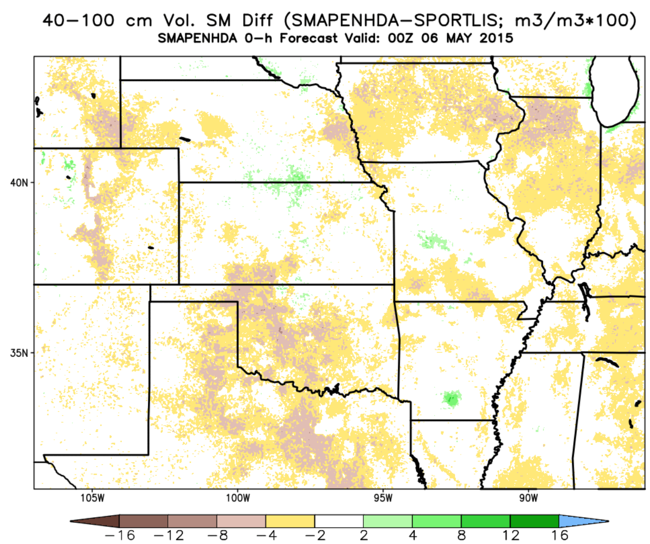
NASA Unified-WRF (NU-WRF) model runs:

Soil Moisture Initial Condition Differences on 3-km nest

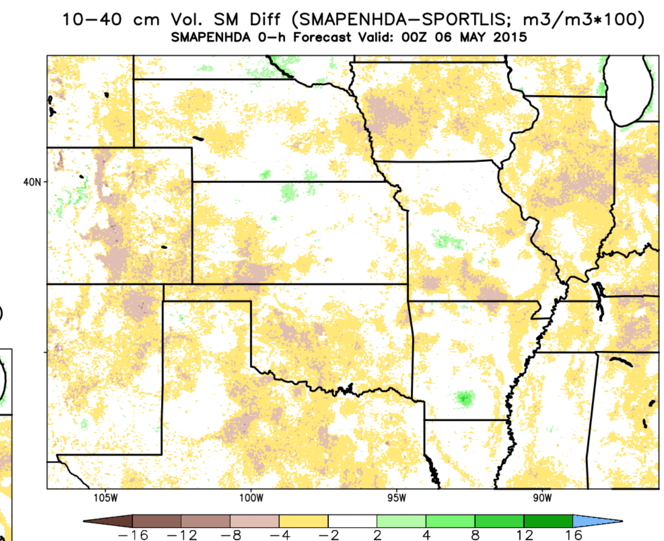


Top soil layer (0-10 cm)

SMAP-Enhanced data assimilation run generally produced drier soil moisture fields than sportlis.



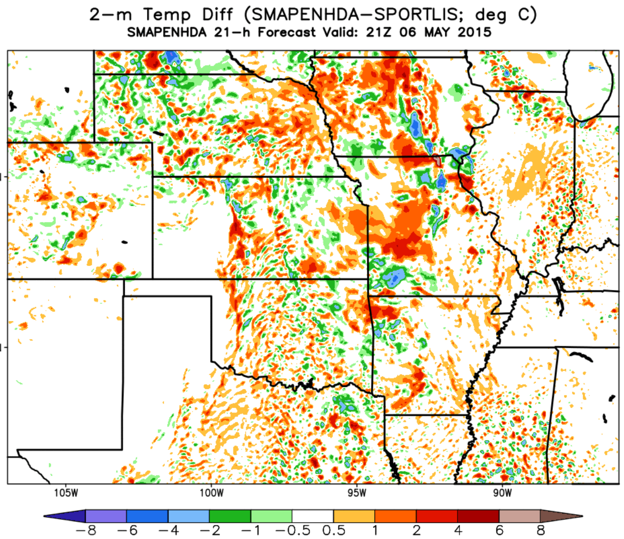
Soil layer 3 (40-100 cm)



Soil layer 2 (10-40 cm)

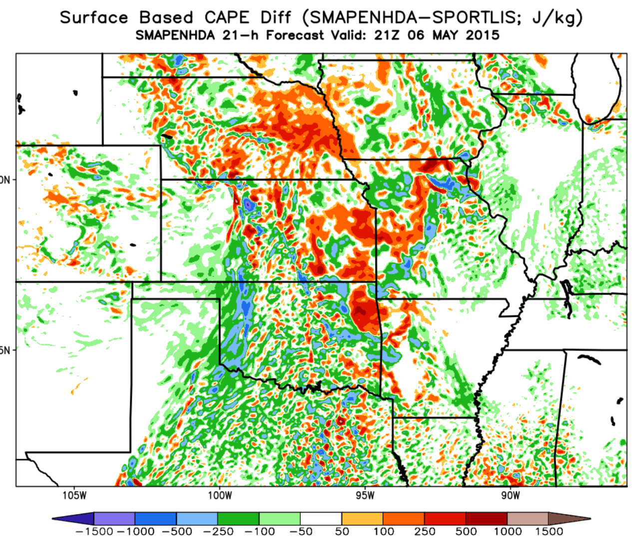
NASA Unified-WRF (NU-WRF) model runs:

Slight improvement in simulated convective evolution

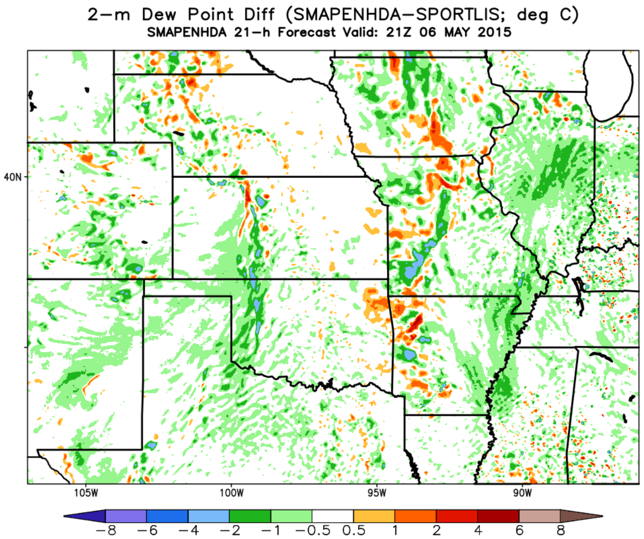


2-m Temperature

smapenhda-initialized NU-WRF runs generally simulated warmer/drier daytime temperatures/dewpoints, with slightly lower instability where convection/supercells developed.



Sfc-based Convective Available Potential Energy

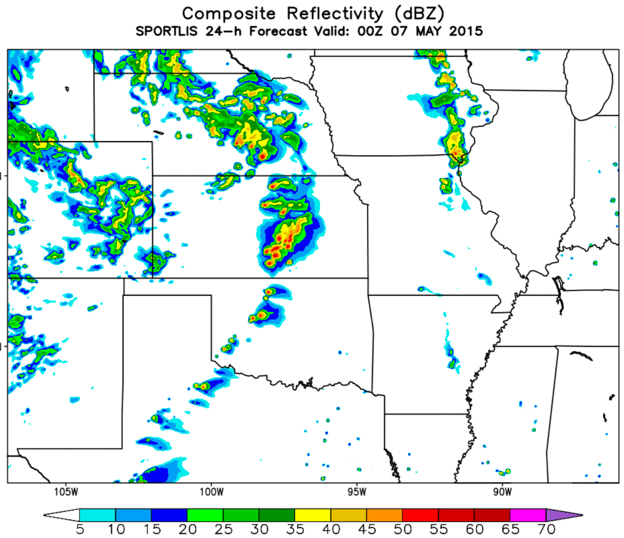


2-m Dewpoint Temperature

*****All simulated fields shown are from the 21-hour NU-WRF forecast, valid on 2100 UTC 6 May 2017***

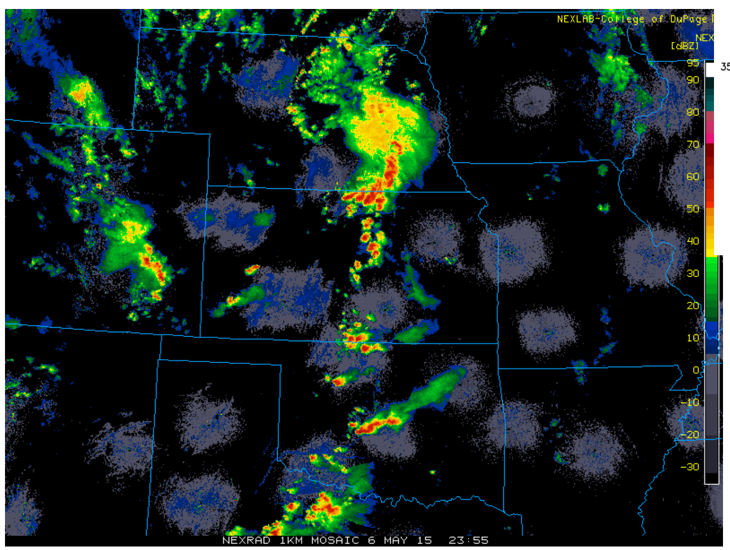
NASA Unified-WRF (NU-WRF) model runs:

Slight improvement in simulated convective evolution

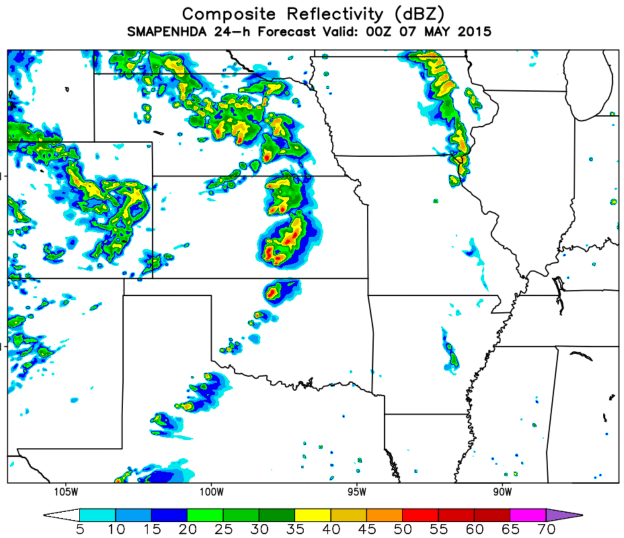


sportlis-initialized NU-WRF run

smapenhda-initialized NU-WRF runs more correctly retained convection in southern OK and northern TX into the overnight hours of 7 May 2015.



Observed regional radar reflectivity (dBZ)

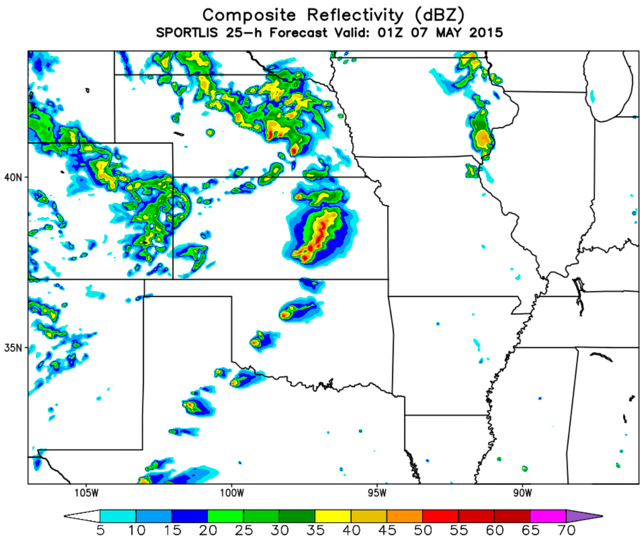


smapenhda-initialized NU-WRF run

24-hour NU-WRF forecasts and observed radar imagery valid at 0000 UTC 7 May 2015

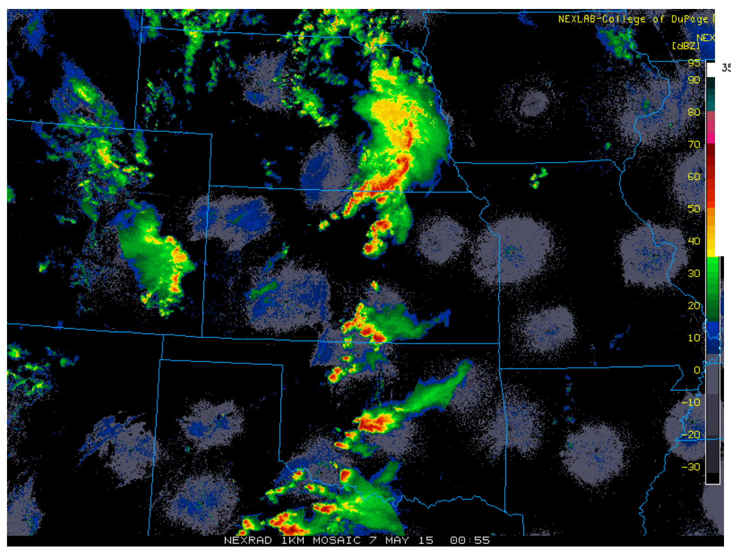
NASA Unified-WRF (NU-WRF) model runs:

Slight improvement in simulated convective evolution

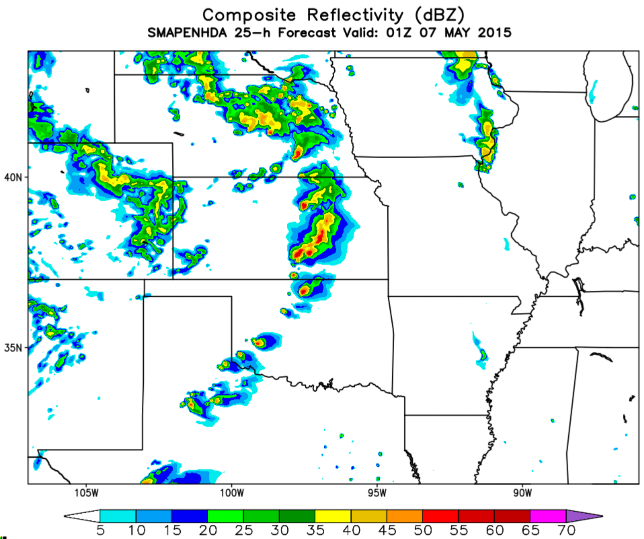


sportlis-initialized NU-WRF run

smapenhda-initialized NU-WRF runs more correctly retained convection in southern OK and northern TX into the overnight hours of 7 May 2015.



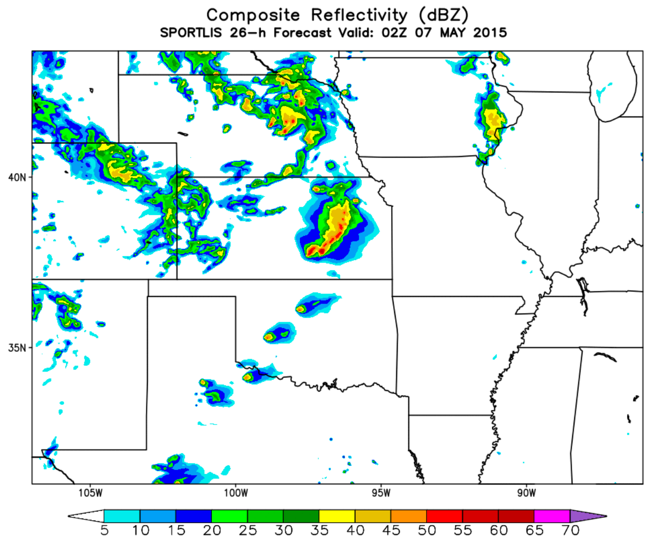
Observed regional radar reflectivity (dBZ)



smapenhda-initialized NU-WRF run

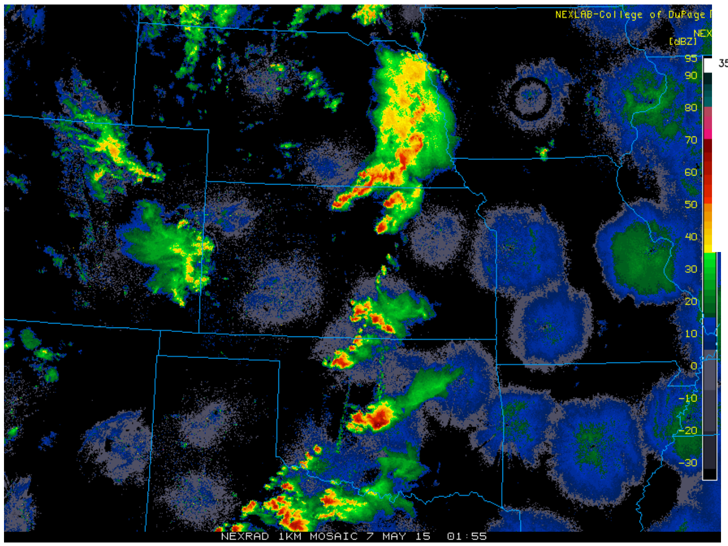
25-hour NU-WRF forecasts and observed radar imagery valid at 0100 UTC 7 May 2015

NASA Unified-WRF (NU-WRF) model runs:
Slight improvement in simulated convective evolution

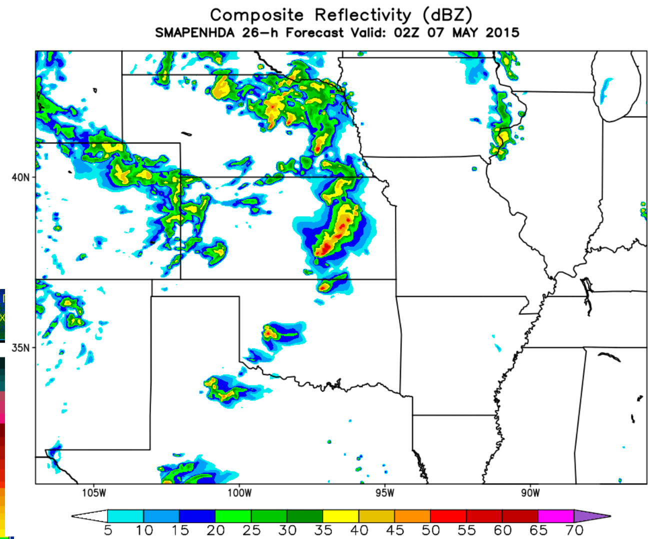


sportlis-initialized NU-WRF run

smapenhda-initialized NU-WRF runs more correctly retained convection in southern OK and northern TX into the overnight hours of 7 May 2015.



Observed regional radar reflectivity (dBZ)

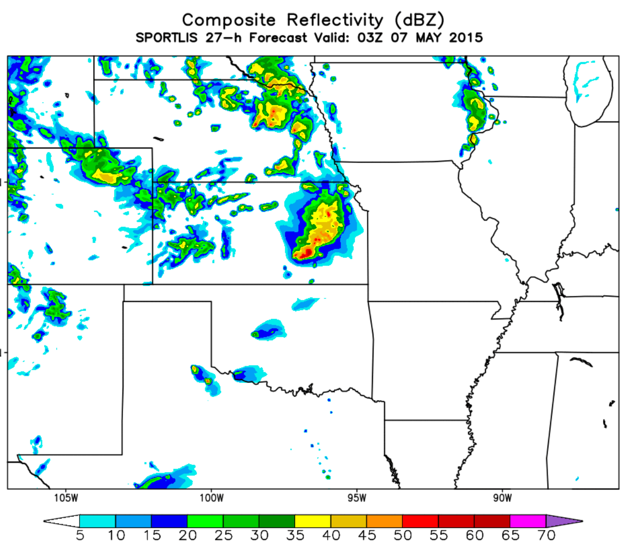


smapenhda-initialized NU-WRF run

26-hour NU-WRF forecasts and observed radar imagery valid at 0200 UTC 7 May 2015

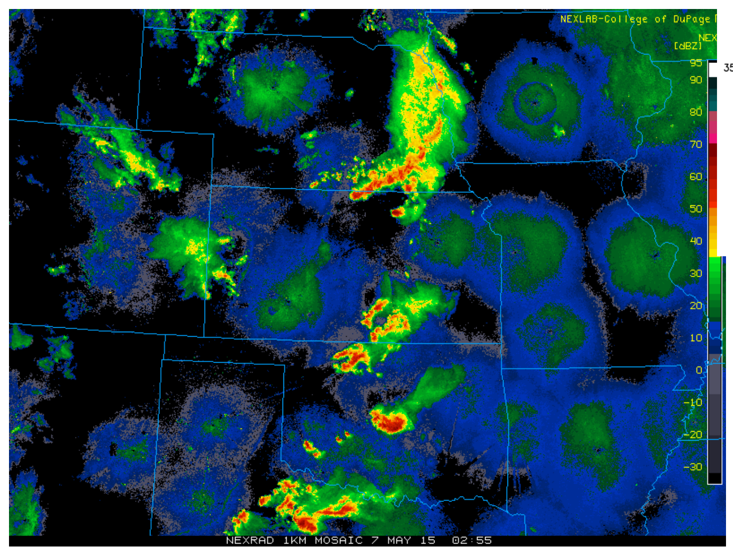
NASA Unified-WRF (NU-WRF) model runs:

Slight improvement in simulated convective evolution

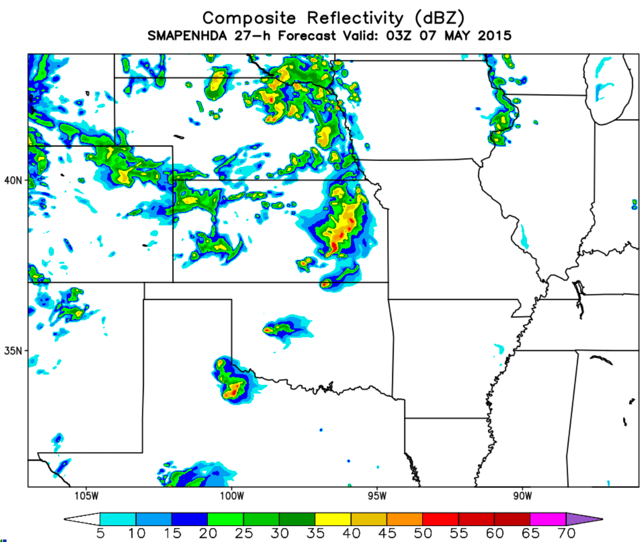


sportlis-initialized NU-WRF run

smapenhda-initialized NU-WRF runs more correctly retained convection in southern OK and northern TX into the overnight hours of 7 May 2015.



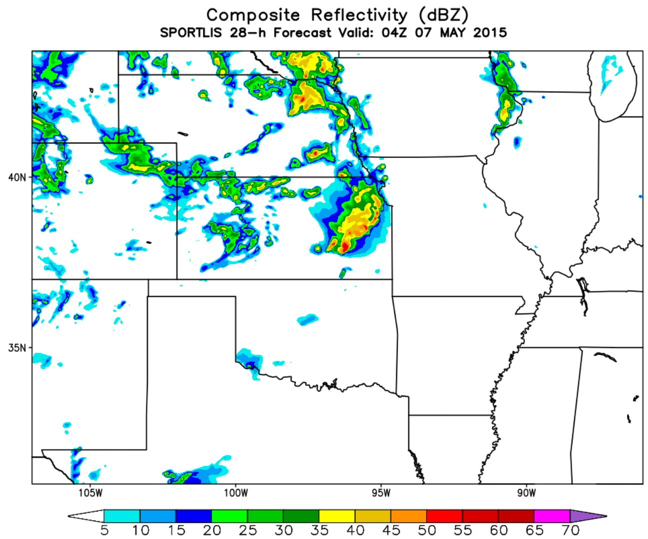
Observed regional radar reflectivity (dBZ)



smapenhda-initialized NU-WRF run

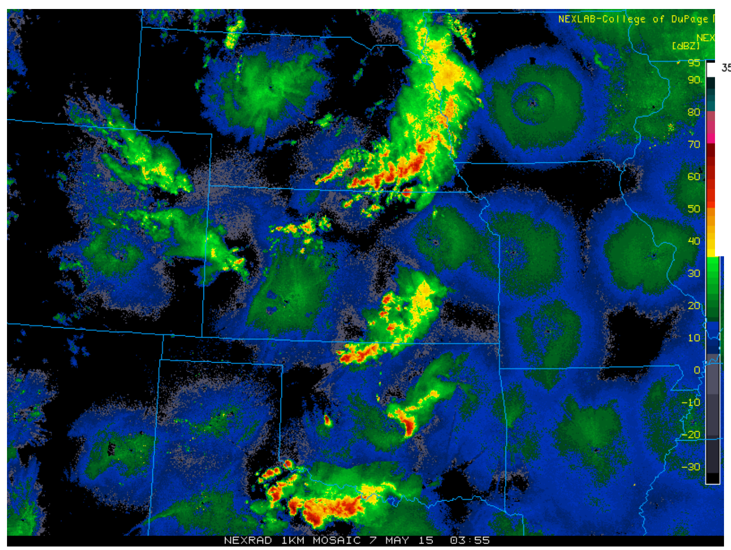
27-hour NU-WRF forecasts and observed radar imagery valid at 0300 UTC 7 May 2015

NASA Unified-WRF (NU-WRF) model runs:
Slight improvement in simulated convective evolution

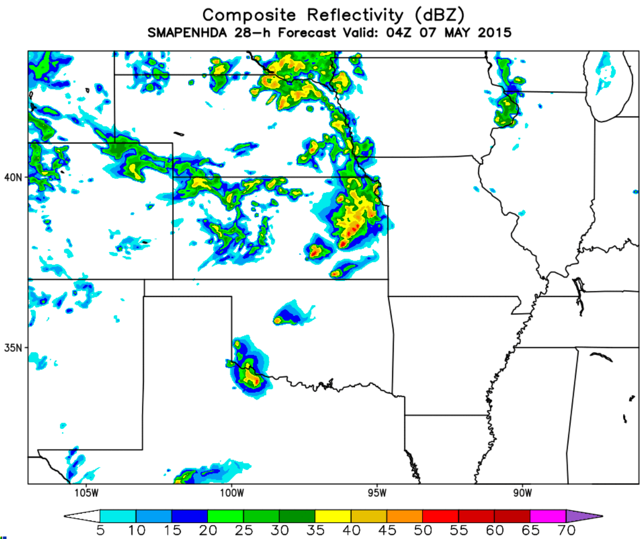


sportlis-initialized NU-WRF run

smapenhda-initialized NU-WRF runs more correctly retained convection in southern OK and northern TX into the overnight hours of 7 May 2015.



Observed regional radar reflectivity (dBZ)

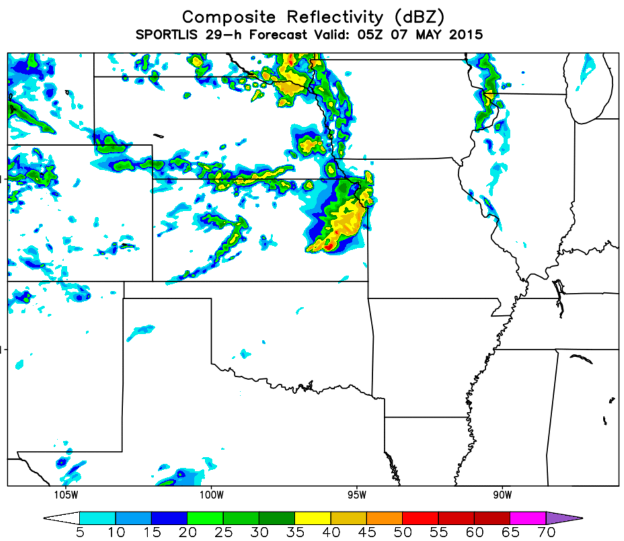


smapenhda-initialized NU-WRF run

28-hour NU-WRF forecasts and observed radar imagery valid at 0400 UTC 7 May 2015

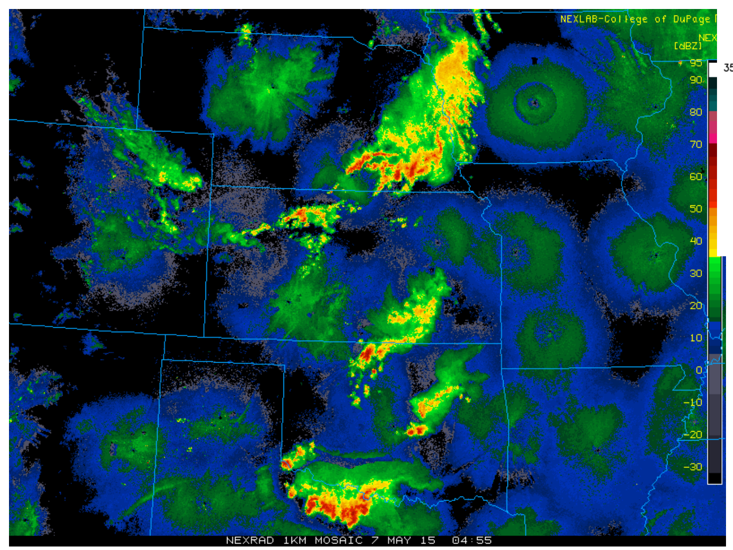
NASA Unified-WRF (NU-WRF) model runs:

Slight improvement in simulated convective evolution

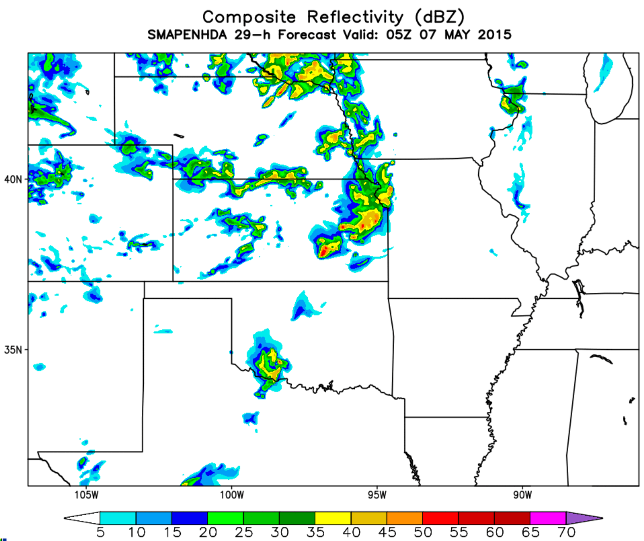


sportlis-initialized NU-WRF run

smapenhda-initialized NU-WRF runs more correctly retained convection in southern OK and northern TX into the overnight hours of 7 May 2015.



Observed regional radar reflectivity (dBZ)

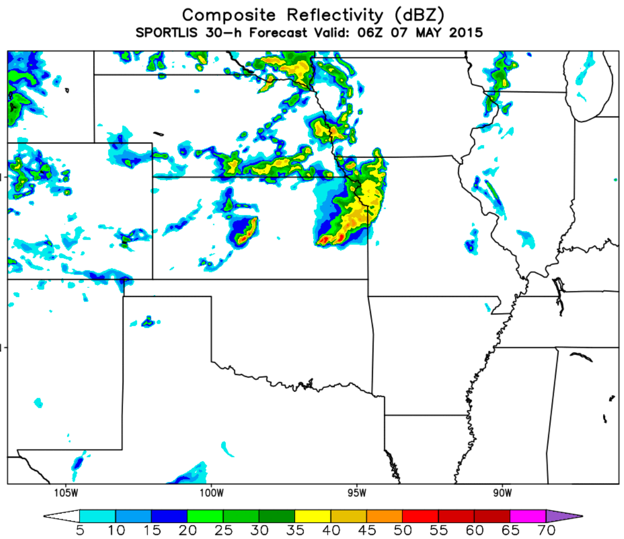


smapenhda-initialized NU-WRF run

29-hour NU-WRF forecasts and observed radar imagery valid at 0500 UTC 7 May 2015

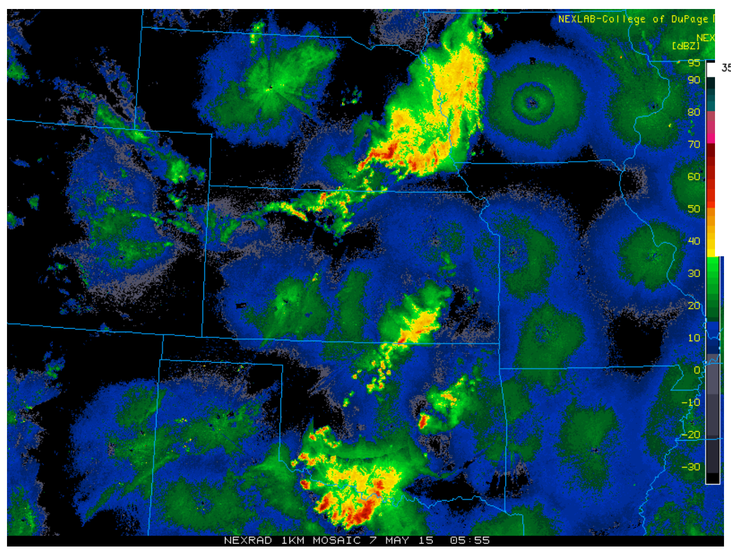
NASA Unified-WRF (NU-WRF) model runs:

Slight improvement in simulated convective evolution

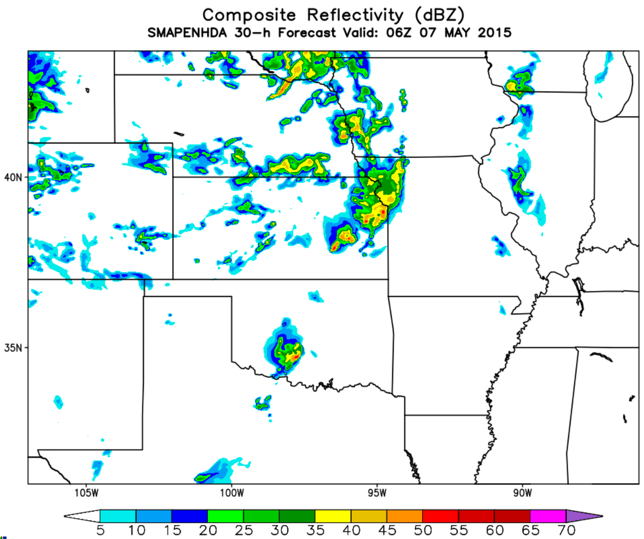


sportlis-initialized NU-WRF run

smapenhda-initialized NU-WRF runs more correctly retained convection in southern OK and northern TX into the overnight hours of 7 May 2015.



Observed regional radar reflectivity (dBZ)

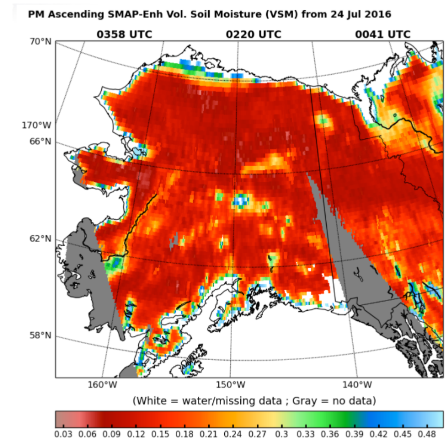


smapenhda-initialized NU-WRF run

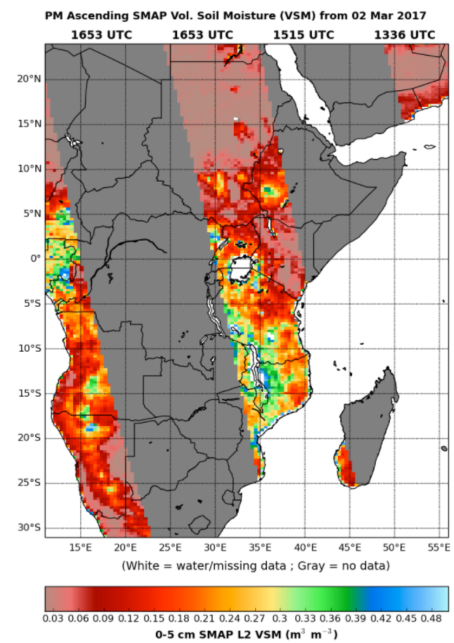
30-hour NU-WRF forecasts and observed radar imagery valid at 0600 UTC 7 May 2015

Future Plans

- Soil Moisture
  - Validation of soil moisture against ground probes
  - Investigation of bias correction methods
- Coupled NWP
  - Validation of 48-hr NWP forecasts
    - High-impact case studies
    - Comprehensive seasonal validation
- Africa domain
- Possible Alaska domain



SMAP L2 Enhanced SM



https://weather.msfc.nasa.gov/sport
->Realtime Data
->SMAP Soil Moisture

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- SMAP Science Team and Early Adopters Team
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  (ROSES 2015 Science Utilization of SMAP Mission Program)

Questions and Comments?

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http://weather.msfc.nasa.gov/sport/

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